PHYSIOLOGY

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NOTES

ON

PHYSIOLOGY

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PREFACE

TO

THE SECOND EDITION.

In preparing the Second Edition, the text has been carefully revised, some new matter added, and several sections entirely re-written.

H. A.

Manchester: *March*, 1880.

PREFACE

TO

THE FIRST EDITION.

These Notes were originally compiled for the use of students of the Liverpool School of Medicine, when preparing for the primary examination of the College of Surgeons. They now appear in print, in the hope that they may prove useful to a wider class of students. The information they contain is founded, to a large extent, on Quain's 'Anatomy' (8th ed.), Gray's 'Anatomy,' and Foster's 'Text-Book of Physiology,' to which works the student is referred for his general reading. Fifty questions, taken for the most part from the Calendar of the College of Surgeons, are added.

H. A.

Manchester: *Sep.* 1878.

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SECTION I.

PHYSIOLOGICAL CHEMISTRY.

The ultimate constituents of the human body comprise some fifteen or sixteen of the elements. They are—

Oxygen	Sulphur	Sodium	Silicon
Hydrogen	Phosphorus	Potassium	Fluorine
Carbon	Chlorine	Magnesium	Lithium
Nitrogen	Calcium	Iron	Manganese

These elements are combined in various proportions, to form the compounds which exist in the tissues of the body. The simpler bodies are crystalline, as urea; the more complex, as albumen, are amorphous. The former, being crystalloids, readily pass out of the body through the excretory organs; the latter, being colloids, are better suited to form part of its tissues.

They may be divided into the following classes:—

I. Inorganic Salts.
II. Organic Crystalline Salts.
III. Carbo-hydrates, or Sugars.
IV. Hydro-carbons, or Fats and their allies
V. Albuminous, or Proteid Compounds.
VI. Albuminoid, or Gelatinous Compounds.

I. The INORGANIC SALTS include the bases before mentioned in combination with acids, the principal being chlorides, carbonates, phosphates, and sulphates; sulphocyanides, fluorides, and nitrates occur in small quantities.

II. The ORGANIC CRYSTALLINE BODIES are very numerous; for the most part they are the result of the disintegration of albuminous material, and nearly all contain nitrogen. The principal members of this group are urea, uric acid, xanthin, hypoxanthin, hippuric acid, kreatin, kreatinin, lactic acid, lecithin, neurin, cerebrin, leucin, tyrosin, and cholesterin.

Urea, CH_4N_2O or $(NH_2)_2CO$, forms the chief constituent of the solid portions of the urine. It exists also in small quantities in the blood and liver, liq. amnii, and serous fluids.

Preparation—artificially: By heating a mixture of potassic ferrocyanide and manganic dioxide on an iron sheet, potassic cyanate is formed, and is dissolved out with water. The potassic cyanate is treated with ammonium sulphate, ammonium cyanate and potassic sulphate being formed; the potassic salt is removed by crystallisation, and the mother liquor, on evaporation to dryness, and extraction of the dried residue with alcohol, yields urea.

From urine: The urine is evaporated to a thin syrup, and its own volume of colourless nitric acid

added; nitrate of urea is formed and readily crystallises. The nitrate is decolourised by animal charcoal and recrystallised. To obtain the urea pure, the nitrate is decomposed by potassic carbonate, the potassic nitrate which is formed is allowed to crystallise out, and the liquor containing urea evaporated to dryness and extracted with alcohol.

Properties.—Urea crystallises from water in long thin colourless needles. If formed slowly the crystals are four-sided, and have pyramidal ends. It is a colourless substance of saline taste, soluble in water and alcohol, insoluble in ether. Urea is closely related (being isomeric) with ammonium cyanate, NH_4CNO, and carbamide, $(NH_2)_2\,CO$.

Characteristic reactions.—(1.) Pure nitric acid gives in a strong solution of urea a crystalline precipitate of urea nitrate. These crystals are colourless six-sided prisms, and are sparingly soluble in alcohol.

(2.) Mercuric nitrate gives a white precipitate in the absence of chlorides.

(3.) Nitrous and hypobromous acids decompose urea, nitrogen and carbonic acid being liberated.

(4.) Fused with caustic potass, or treated with concentrated sulphuric acid, urea is resolved into ammonia and carbonic acid. The same change takes place in the presence of decomposing animal matters as in stale urine, the urine becoming ammoniacal:—

$$CO(H_2N)_2 + 2H_2O = (NH_4)_2CO_3.$$
Urea + aq. = ammonium carbonate.

Uric Acid, $C_5H_4N_4O_3$, is present in small quantities in the urine, in combination with a base. It is present in the spleen, liver, and also in the blood, in gout, and urinary calculi are often composed of it. It forms about 90 per cent. of the solid residue of the urine of snakes, and is present in large proportion in the urine of birds.

Preparation.—It is best obtained from the excrement of snakes, by boiling with caustic potass until the urate of ammonium of which it consists is decomposed, ammonia being evolved. The uric acid is precipitated in an impure state by adding hydrochloric acid. The precipitate is re-dissolved in potass and re-precipitated by acid.

From urine.—By acidulating with hydrochloric acid, and allowing to stand for twenty-four hours, reddish crystals of impure uric acid being precipitated.

Properties.—Pure uric acid is a white crystalline powder, almost insoluble in cold water, insoluble in alcohol and ether. The crystals vary in shape, but are for the most part of a rhombic form. It is dibasic, and combines with bases to form soluble salts, as the urates of ammonium, potassium and sodium.

Tests—Murexide test.—A small portion of uric

acid is moistened with strong nitric acid, and evaporated at a gentle heat. It effervesces, and leaves a reddish colouration, which on adding ammonia becomes purple.

Schiff's Test.—Uric acid is dissolved in a solution of sodium carbonate and dropped on paper moistened with silver nitrate; a brown stain is formed.

Xanthin, $C_5H_4N_4O_2$, exists in small quantities in urine, in the spleen, and muscles. It is insoluble in water, soluble in nitric and hydrochloric acid. When heated with nitric acid and evaporated, a yellow residue is left. It occurs in some calculi.

Hypoxanthin, $C_5H_4N_4O$, occurs in the tissues of the spleen and muscles, and has been noticed in the urine of leukamia; when oxidised it forms xanthin.

Hippuric acid, $C_9H_9NO_3$, occurs in small quantities in the urine of man and carnivora, but abundantly in the urine of herbivora. It is precipitated by iron salts; most of its other salts are soluble. It crystallises in fine needles.

Kreatin, $C_4H_9N_3O_2$, exists in the muscles, and can be obtained from extract of meat. It occurs in colourless rhombic prisms. Soluble in hot, sparingly soluble in cold water. It has a neutral reaction, and when boiled with baryta water, splits up into urea and sarcosin.

Kreatinin, $C_4H_7N_3O$, is an alkaline body which

exists in small quantities in muscle-extract and in urine. It crystallises in colourless prisms. Kreatin, on boiling with HCl, takes up H_2O and forms kreatinin. It can be separated from the urine by precipitating with mercuric chloride.

Lactic acid, $C_3H_6O_3$, is the acid formed during lactic fermentation, and is found in sour milk and in the alimentary canal. *Sarço-lactic acid* has the same composition as lactic, but differs from it in the solubility and crystalline form of its zinc and calcium salts. It is found in the muscles, and can be obtained from muscle-extract.

Cholesterin, $C_{26}H_{44}O$, is a neutral crystalline body (in reality an alcohol), which occurs in bile, in the brain, spinal cord, and many pathological fluids. It is readily prepared by boiling gall-stones in alcohol, filtering, and allowing to crystallise. With strong H_2SO_4 and a trace of iodine it becomes of a violet colour, which afterwards changes to green and then red.

Lecithin, $C_{44}H_{90}NPO_3$, occurs in the brain, yolk of egg, pus, and in smaller quantities in the blood and bile. It is a white crystalline substance, soluble in hot alcohol and ether.

Cerebrin and **Neurin** are two substances which occur in the brain, and the latter also in yolk of egg.

Leucin, $C_6H_{13}NO_2$, in conjunction with tyrosin, is found in many of the organs and fluids of the body, in the pancreas, liver, spleen, in the peptones

of the alimentary canal, and in the urine in acute yellow atrophy and other diseases of the liver. These substances are formed during the decomposition of albuminous substances. They may be prepared by the artificial decomposition of albumen, fibrin, casein, gelatin, &c., but are most readily obtained by boiling horn-chips in dilute sulphuric acid. Leucin can also be obtained synthetically. Impure leucin appears under the microscope in the form of oily lumps clustering together; when pure it forms white flat crystals. It is soluble in water and alkalies, less so in alcohol.

Scherer's Test.—Place a small portion on platinum foil with a drop of nitric acid and evaporate gently. A colourless residue will be left, which, on the addition of liq. potassæ, will become yellow and form an oily drop.

Tyrosin, $C_9H_{11}NO_3$, is generally found in connection with leucin, and consists of minute colourless microscopic needles of a silky lustre. It is less soluble in water than leucin, and is insoluble in alcohol, but soluble in liq. potassæ and dilute acids.

Hoffman's Test.—Add mercuric nitrate and boil; the liquids will become rose-coloured and deposit a red precipitate.

Piria's Test.—Add a few drops of concentrated sulphuric acid, warm, neutralise with chalk, filter, and add ferric chloride; the liquid will become of a violet colour.

III. Carbo-Hydrates.—The principal carbo-hydrates found in the animal body are: 1. Grape sugar. 2. Milk sugar. 3. Inosit. 4. Glycogen. 5. Dextrin.

1. **Grape Sugar or Dextrose,** $C_6H_{12}O_6$, occurs in small quantities in the blood and urine, and in larger quantities in the contents of the alimentary canal. It is formed in the mouth and intestines by the action of the saliva on the starch and cane sugar present in the food. When pure it forms four-sided prisms, but is generally seen in irregular warty lumps. It is soluble in water and alcohol. It undergoes decomposition in the presence of certain ferments.

(*a*) *Alcoholic* fermentation takes place under the influence of yeast; alcohol and carbonic acid are formed,

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

(*b*) *Lactic fermentation.*—Under the influence of decomposing animal matters, lactic acid is formed in the first instance and afterwards butyric acid, carbonic acid and hydrogen.

1st stage, $C_6H_{12}O_6 = 2C_3H_6O_3$

2nd stage, $2C_3H_6O_3 = C_4H_8O_2 + 2CO_2 + 2H_2$

The acidity of the contents of the large intestine is due to the presence of lactic acid.

Trommer's Test.—Boil the solution with a few drops of solution of cupric sulphate and excess of caustic potass; if dextrose is present an

abundant reddish-yellow precipitate of cuprous oxide will fall.

Moore's Test.—Boil with caustic potass; if sugar is present the liquid will become first light yellow and afterwards brown.

Fermentation Test.—Add a small quantity of yeast, and leave in a warm place for 24 hours; a considerable quantity of carbonic acid will be evolved, which can be collected in a suitable apparatus. Alcohol will be present in the liquid.

2. **Milk Sugar or Lactose,** $C_{12}H_{22}O_{11}$, is found in milk. It differs from dextrose in being more insoluble in water and not readily undergoing the alcoholic fermentation. It readily undergoes the lactic fermentation. It precipitates cuprous oxide from alkaline solutions in the same manner as dextrose. It is insoluble in alcohol.

3. **Inosit,** $C_6H_{12}O_6$, occurs in small quantities in the spleen, liver, and brain, and appears in the urine in uræmia. It undergoes the lactic but not the alcoholic fermentation.

4. **Glycogen,** $C_6H_{10}O_5$, is found in considerable quantities in the liver of well-fed animals, in smaller quantities in the white corpuscles of the blood, placenta and fœtal tissues. It is an amorphous, white tasteless powder soluble in water, insoluble in alcohol. Its aqueous solution is opalescent.

Preparation.—Kill a well-fed rabbit shortly after a meal, quickly remove the liver, and after cutting

it in slices, throw it into boiling water without loss of time. After boiling for a short time (to prevent the ordinary post-mortem change which glycogen undergoes into grape sugar), pound the liver, boil again and filter. The filtrate contains the glycogen and certain albuminous substances which must be removed. The latter are precipitated with potassio-mercuric iodide in the presence of hydrochloric acid. The glycogen is then precipitated by adding alcohol.

Tests.—Dilute mineral acids (except nitric) convert it into grape sugar. Iodine gives a red colouration, which disappears on warming and reappears on cooling. (*Starch* gives blue with iodine, *dextrin* red, but disappears on warming, and does not reappear on cooling.)

5. **Dextrin,** $C_6H_{10}O_5$.—Starch is converted into dextrin by the action of ferments, the dextrin formed being in turn converted into dextrose if the action of the ferment is continuous. Dextrin is found in the alimentary canal and also in the blood. It becomes of a red colour on addition of iodine; the colour disappears on warming and does not, as in the case of glycogen, reappear on cooling.

IV. Hydro-Carbons or Fats.—The principal fats present in the animal body are:

$$\text{Stearin} \quad \left.\begin{matrix} C_3H_5 \\ (C_{18}H_{35}O)_3 \end{matrix}\right\} O_3$$

$$\text{Palmitin} \left.\begin{matrix} C_3H_5 \\ (C_{16}H_{31}O)_3 \end{matrix}\right\} O_3$$

$$\text{Olein} \left.\begin{matrix} C_3H_5 \\ (C_{18}H_{33}O)_3 \end{matrix}\right\} O_3$$

These neutral fats, when submitted to the action of superheated steam, or heated with lead oxide, combine with water, and form glycerine and a fatty acid.

$$\underset{\text{Palmitin.}}{\left.\begin{matrix} C_3H_5 \\ (C_{16}H_{31}O)_3 \end{matrix}\right\} O_3} + 3\left.\begin{matrix} H \\ H \end{matrix}\right\} O = \underset{\text{Glycerine.}}{\left.\begin{matrix} C_3H_5 \\ H_3 \end{matrix}\right\} O_3} + 3\,\underset{\text{Palmitic acid.}}{\begin{matrix} C_{16}H_{31}O \\ H \end{matrix} O.}$$

Stearin is best obtained from beef or mutton suet. It is the hardest of the fats, and crystallises in white shining plates. It has the highest melting point (60° C.)

Palmitin is best prepared from palm oil; it crystallises in needles and has a lower melting point than stearin (40° C.)

Olein is prepared from olive oil, and is fluid at ordinary temperatures.

Glycerine, $C_3\left.\begin{matrix} H_5 \\ H_3 \end{matrix}\right\} O_3$, is a syrupy fluid with sweet taste and a neutral reaction; it is soluble in water and alcohol, but not in ether. It dissolves many metallic oxides, and on heating decomposes, acrolein being formed.

V. THE ALBUMINOUS BODIES OR PROTEIDS occur in almost all the tissues and fluids of the body. They derive their name from the white of egg, which is

taken as a type of the group. They will not crystallise, and are obtained pure with difficulty. They are insoluble in alcohol and ether, soluble in strong acids and alkalis, undergoing decomposition in the process. With the exception of the peptones they are coagulated by heat, and will not diffuse through animal membranes. They are not formed in the animal body, but enter the body in the form of food derived from the vegetable kingdom. They have the following average percentage composition :—

O . . .	21	per cent.
H . . .	7·5	,, ,,
C . . .	54	,, ,,
N . . .	16	,, ,,
S . . .	1	,, ,,

Tests.—1. *Xanthoprotein Reaction.*—Heat with strong nitric acid, cool, and add ammonia. An orange colour is produced.

2. *Millon's Reaction.*—Add some Millon's reagent ($Hg(NO_3)_2 + HgNO_3$) and heat; the fluid will become red, and if sufficient albumin is present, a precipitate will fall.

3. Add some liq. potassæ and a drop or two of solution of cupric sulphate; heat : a violet colour is produced.

The albuminous bodies include several groups—

1. Albumin and its derivatives.
2. Globulins. 3. Fibrin. 4. Peptones.

1. **Albumin** is soluble in water, insoluble in alcohol and ether. It is coagulated at a temperature of 70° C. If dried at a lower temperature, it forms a tasteless yellow mass. Albumin is precipitated in the following ways :—

(*a*) By boiling and acidulating with nitric acid.
(*b*) By concentrated nitric acid in the cold.
(*c*) By the addition of acetic acid and potassic ferrocyanide.
(*d*) Boiling with acetic acid and strong solution of sodium sulphate.

Albumin exists in two forms—egg albumin and serum albumin.

They differ in that—

(*a*) Egg albumin is coagulated by ether, serum albumin is not.
(*b*) Coagulated serum albumin is soluble in strong HNO_3, egg albumin is not.
(*c*) Serum albumin injected beneath the skin does not appear in the urine, egg albumin does.

Alkali Albuminate.—If albumin in solution is treated with dilute caustic potash and gently warmed, some of its properties undergo change.

The alkaline solution will no longer be precipitated by boiling. It is precipitated on neutralisation with acids, and is soluble in excess of the acid. It is not precipitated on neutralisation in presence of the alkaline phosphates.

Casein.—This substance closely resembles alkali albuminate, but differs from it in containing sulphur. It can readily be prepared from milk by saturating with magnesium sulphate, or by acidifying and gently warming; it is precipitated when milk comes in contact with the walls of the stomach.

Acid Albumin.—If albumin in solution is treated with HCl or other acids, it undergoes a change in its properties. It is no longer coagulated by heat. It is precipitated on neutralisation with an alkali, and is redissolved by excess: its precipitation is not prevented by alkaline phosphates. It is precipitated on boiling with lime-water. If muscle be dissolved in dilute HCl, a body termed *syntonin*, closely resembling, if not identical with, acid albumin, is formed.

2. **Globulins.**—These bodies differ from the albumins in being insoluble in water, precipitated by CO_2, or on saturating their solutions with NaCl. They are converted into acid albumin by HCl. They are soluble in dilute solutions of NaCl, the solution being precipitated by heat.

They include (*a*) globulin, (*b*) paraglobulin, (*c*) fibrinogen, (*d*) myosin, (*e*) vitellin.

(*a*) **Globulin** exists in the crystalline lens, and closely resembles paraglobulin in its properties, but differs from it in not assisting to form fibrin.

(*b*) **Paraglobulin** occurs in blood and serum, and in smaller quantities in some of the tissues. It gives rise to fibrin when mixed with any fluid, as hydrocele fluid, containing fibrinogen.

(*c*) **Fibrinogen** exists in blood, pericardial, pleural, and hydrocele fluids. It closely resembles paraglobulin, but when thrown down by CO_2 it is less flocculent and more viscous.

(*d*) **Myosin** is present in dead muscle. It is not so soluble as fibrinoplastin. It is converted into syntonin by dissolving in HCl.

(*e*) **Vitellin** exists in yolk of egg; it is soluble in dilute NaCl solutions, but differs from other members of the group in not being precipitated by saturating with NaCl.

3. **Fibrin** is obtained by whipping freshly-drawn blood. It forms tough, white strings, which are insoluble in water and dilute NaCl solutions; is converted into syntonin by digestion with HCl.

4. **Peptones** are distinguished from other albuminous bodies by not being precipitated by boiling, acids, or by potass. ferrocyanide and acetic acid. They diffuse through animal membranes. They are precipitated by tannin, iodine, and acetate of lead.

Several different peptones exist.

VI. The Albuminoids or Gelatinous Bodies. These substances, which occur as the principal constituents of many tissues, resemble the albuminous bodies in their composition, but differ from them in many of their reactions.

They include—

1. Mucin.	3. Chondrin.
2. Gelatin.	4. Elastin.

1. **Mucin** is found in fœtal connective tissue and in tendons. It occurs also in the mucous secretions, saliva, bile, gastric juice, &c., giving them their ropy consistence. It is not coagulated by boiling. It is precipitated by acetic acid. It gives the proteid action with Millon's reagent and nitric acid, but not with sulphate of copper and liq. potass.

2. **Gelatin.**—Bones, connective tissues, tendons yield gelatin on boiling. When dry it is a colourless, transparent body; it swells up in cold, and dissolves in hot water; the solution, on cooling, forms a jelly. It is precipitated by tannic acid and mercuric chloride, not by acetic acid. It does not yield the proteid reactions with nitric acid, Millon's reagent, or copper sulphate.

3. **Chondrin** forms the bulk of the matrix of cartilage, and can be prepared by boiling cartilaginous substances in water, the solutions forming a

jelly on cooling. It is precipitated by acetic acid and lead acetate.

4. **Elastin.**—The yellow elastic fibres present in the liq. subflava, and other parts of the body, consist of elastin. It does not dissolve in boiling water, but is soluble in boiling caustic potass.

SECTION II.

PHYSIOLOGICAL HISTOLOGY.

EPITHELIUM.

THE various free surfaces of the body—as, for example, the external surface of the skin, the mucous membranes, the internal membrane of the arteries, and the serous sacs—are lined by cells of different characters, which form the epithelium or endothelium. The latter term is applied by some to the flattened cells which line the serous sacs, blood-vessels, and lymphatics.

The epithelial cells differ very considerably in shape and size, but they agree in possessing nuclei and finely granular cell-contents. This granular protoplasm has recently been shown to consist of a fine network, the meshes of which contain a hyaline material. The nucleus in like manner consists of a fine network, hyaline material, and has also a limiting membrane (Klein). Epithelial cells are connected together by a small quantity of a homogeneous albuminous substance, which is termed the intercellular cement.

Epithelium may be divided into the following varieties :—

1. Tesselated or squamous.
2. Columnar.
3. Transitional.
4. Glandular.
5. Ciliated.

1. The **Tesselated** or **Squamous variety** is arranged either as a (*a*) single layer, or (*b*) in superimposed or stratified layers.

(*a*) A single layer of tesselated epithelium is found lining the pleura, pericardium, peritoneum, arachnoid, arteries, veins, capillaries, lymphatic vessels, acini of the lungs, anterior and posterior aqueous chambers of the eye. The cells consist of a thin plate with an oval nucleus, but differ considerably in shape; those lining the serous sacs being polyhedral or nearly circular, the cells lining the arteries and capillaries being elongated, and the lymphatics having epithelium, with an irregular or wavy border. The outline of these cells is readily shown by staining their intercellular cement with silver nitrate.

(*b*) The superimposed layers consist of strata of cells, which clothe surfaces specially liable to friction. They cover the true skin, forming the epidermis; they form the superficial layer of the mucous membrane of the cavity of the mouth, tongue, œsophagus,

conjunctiva, and vocal cords, vagina, external aperture and fossæ navicularis of the urethra. The deeper cells of the dermis are more or less round, though the deepest are columnar, and form the rete mucosum ; the superficial cells are flattened, forming the horny layer or stratum corneum, which covers the soles of the feet and palms of the hand.

2. **Columnar.**—This variety consists of cylindrical or club shaped nucleated cells, the thick ends being towards the free surface. They are found lining the alimentary canal from the œsophageal end of the stomach to the anus, lining the ducts of glands and the olfactory region of the nose.

3. **Transitional.**—This variety consists of flattened cells on the surface, a middle layer of pear-shaped cells, their rounded ends fitting into the under surface of the flattened cells, and an inferior layer of rounded or pyriform cells fitting between the thin ends of the middle layer. The bladder, ureters, pelvis of kidney, are lined by transitional epithelium, and also the larynx and pharynx, where the columnar and flattened cells come in contact.

4. **Glandular.**—The acini of the various glands of the body, as the convoluted tubes of the kidney, the salivary and peptic glands, are lined by spheroidal or cubical cells. These cells are nucleated, and probably perform the important work of separating or elaborating from the blood the materials which form the secretion of the gland.

5. **Ciliated.**—In some parts of the body the epithelial cells are provided with minute rods, which are constantly in motion, and serve to propel mucus or any minute particles in contact with them towards the orifice of the chamber or tubes whose walls they line. They vibrate at the rate of about 700 per minute. These minute rods are probably prolongations of the intra-cellular network, and their movements are independent of any nervous mechanism. Chloroform vapour and carbonic acid gas arrest their movements. Weak acids or alkalies and moderate electric currents stimulate them. Ciliated epithelium is for the most part columnar in shape.

They are present in man—

(*a*) Lining the mucous membrane of the air passages. Commencing near the nostrils, they line the nasal cavity (except the olfactory region), the antrum, ethmoidal and frontal sinuses, the nasal and lachrymal ducts, the upper part of the pharynx, the Eustachian tube, tympanic cavity, trachea, and bronchi, till they enter the infundibula of the lungs.

(*b*) Lining the mucous membrane of the uterus, commencing at the middle of the cervix and continuing along the Fallopian tubes to their fimbriated extremities.

(*c*) Lining the vasa efferentia, coni vasculosi, and upper part of the globus major of the testis.

(*d*) Lining the lateral ventricles of the brain and central canal of the spinal cord in the child.

Many of the animalculæ and algæ, as the paramecia, rotifera, vorticella, volvox, are provided with cilia as a means of locomotion, or for producing currents in the water, so as to carry their prey within their reach. Cilia are also found in the gills of the oyster and salt-water mussel, and doubtless serve to bring a fresh supply of oxygenated water in contact with the capillaries of their gills. In man, they probably prevent the accumulation of mucus or foreign particles on the surfaces they line, and possibly in the testicle help forward the immature spermatozoa.

They are most readily obtained for the microscope by snipping a small piece from the gills of the mussel, and covering with thin glass; they will continue to work for hours if evaporation be prevented.

PIGMENT.

PIGMENT is met with in various parts of the body, in the choroid, iris, olfactory region of the nose, pia-mater of the cord, and in some of the cells of the grey matter of the brain. It occurs in some pathological states, as in the rete mucosum in Addison's disease and in melanotic tumours.

The choroid contains hexagonal cells filled with dark matter; on the outer surface of the choroid the cells are branched. The pigment of the choroid

is evidently of use in absorbing any redundant light which enters the eye. Chemically it is characterised by the large percentage (nearly 60 per cent.) of carbon which it contains.

CONNECTIVE TISSUE.

CONNECTIVE TISSUE is present almost universally throughout the body, serving to connect the various organs with one another, as well as to bind together the parts of which an organ consists. The muscles are surrounded by a connective tissue sheath, which also penetrates into their substance, binding together the fasciculi and fibres. The same tissue is present beneath the skin and mucous membranes, and forms a sheath for the arteries, veins, and nerves. It is plentifully supplied with blood-vessels, and many nerves pass through its substance. Microscopically, three different elements may be seen—

1. Corpuscles and nuclei.
2. White fibrous tissue.
3. Yellow fibrous tissue.

1. **Corpuscles.**—These are most readily seen in the subcutaneous tissues of young animals, as in the young of the guinea-pig. Besides the fibres, irregular-shaped nucleated cells will be seen. Many of the cells are branched, the branches anastomosing with one another. These cells occupy spaces which they completely fill. There is a certain amount of

finely granular material between the cells and fibres, which stains with nitrate of silver, the cells and fibres being unstained. The nuclei readily stain with carmine, while the fibres do not.

2. **White Fibrous Tissue** forms the major part of the connective tissue of the body. Microscopically, it consists of white, wavy parallel fibres, which swell up on the addition of acetic acid. On boiling it yields gelatine.

3. **Yellow Fibrous Tissue** forms a variable proportion of connective tissue, being especially abundant beneath the skin, mucous and serous membranes. Microscopically, it consists of yellow, elastic, curling, branching fibres, of a larger size than the fibres of white fibrous tissue. It is unchanged by acetic acid and the weaker alkalies. Chemically it yields elastin.

Distribution of White Fibrous Tissue.—Those connecting tissues of the body which require to be inelastic, tough, unyielding, are formed of pure white fibrous tissue without admixture of yellow. Such are the tendons, fasciæ, aponeuroses, most ligaments, the periosteum, the dura-mater, pericardium, &c. They are white in colour and will not readily stretch. Besides the ordinary wavy fibres, they contain connective tissue corpuscles.

Distribution of Yellow Elastic.—In some parts of the body an elastic material is required to connect bones together or to form the walls of blood-vessels.

Yellow elastic tissue enters largely into the following structures :—

1. Ligamenta subflava of the vertebræ.
2. The stylo-hyoid, thyro-hyoid, crico-thyroid ligaments, the vocal cords, and calcaneo-scaphoid ligament.
3. The middle coat of the larger arteries and veins.
4. It is present beneath the mucous membrane of the trachea, and forms the walls of the infundibula.
5. The capsule and trabeculæ of the spleen, lymphatic glands, and erectile tissues.
6. Forming the ligamentum nuchæ of horse and ox.

RETIFORM TISSUE.

Retiform Tissue consists of a delicate network formed by connective tissue corpuscles joining their branches together. In some parts the corpuscles and their nuclei are very apparent, whilst elsewhere but little can be seen of nuclei at the intersections of the fibres. Retiform tissue forms the stroma or framework of *lymphoid tissue.*

In lymphoid tissue, the spaces in the network are occupied by leucocytes. It is found in lymphatic glands, solitary glands of the intestine, tonsils, spleen, &c.

ADIPOSE TISSUE.

ADIPOSE TISSUE is present in many parts of the body. It forms a layer beneath the skin, in the subcutaneous connective tissues, except beneath the skin of the eyelids and penis; it forms a layer of considerable thickness covering the buttocks, thighs, and abdomen, in well-nourished subjects. In the internal organs it is collected around the kidneys, heart, and folds of the omentum, but it is absent from the cranium and lungs.

Structure.—Beneath the microscope, adipose tissue will be seen to consist of small vesicles, $\frac{1}{300}$ to $\frac{1}{500}$ inch in diameter, with a delicate envelope and containing yellow oily matters. These vesicles are held together and supported by connective tissue, and are plentifully supplied with blood-vessels. A nucleus is sometimes to be seen, though often obscured by the fatty matters. In prepared specimens, crystals, probably of palmitic acid, may be seen occupying the vesicles. The contents of the vesicles in the human body consist of olein, palmitin, and stearin.

Uses.—1. Adipose tissue serves as a convenient packing material, which fits in between the tissues and organs, and from its fatty nature it serves to diminish friction. For example, the subcutaneous fat covering the buttock will form a soft pad, and allow the skin to work smoothly over subjacent structures.

2. Adipose tissue is an excellent non-conductor, and serves to retain the heat of the body.

3. Adipose tissue serves to store up for future use a substance rich in carbon and hydrogen. The destiny of fat is eventually to be converted into CO_2 and H_2O, its oxidation serving to maintain the heat of the body and give rise to muscular energy. Hybernating animals fatten during the autumn on starchy foods, the stored fat serving to maintain them during their winter sleep.

CARTILAGE.

Cartilage is a bluish or yellowish white, semi-translucent elastic substance, without vessels or nerves, and surrounded by a fibrous membrane, the perichondrium. Cartilage, on boiling for some hours, yields an albuminoid called chondrin, which, like gelatin, sets into a jelly on cooling, but differs from gelatin in being thrown down by tannic acid.

Cartilage may be divided into

1. Hyaline: Temporary, Costal, Articular.
2. Fibro-cartilage: White, Yellow.

1. **Hyaline Cartilage** is present in many parts of the body. In the fœtus it forms a firm, elastic material for the skeleton, prior to the deposition of

lime salts and consolidation of the bones. In the adult it supplies an elastic material in the costal cartilages, to assist in forming the walls of the chest, its elasticity aiding in an important manner the expiratory act. It caps the ends of bones at the joints, and helps to diminish friction and lessen shock. It forms in large measure the walls of the trachea and bronchi, serving to maintain their rigidity and prevent collapse.

Structure.—It presents beneath the microscope numerous round or angular nucleated cells scattered through a finely granular matrix. The cells lie in a cavity of the matrix, the cavity being lined by a capsule.

Hyaline cartilage is modified in different situations:—

(*a*) **Temporary.**—Cartilage forms a support for the fœtus, and a bed for the deposition of the lime salts. The cells are small, for the most part angular, provided with tails, and uniformly scattered through the matrix, except where ossification is proceeding, when they arrange themselves in columns. The matrix is very finely granular.

(*b*) **Costal.**—The cells are large and collected into groups, and contain oil globules. The matrix exhibits a tendency to the deposition of lime salts, though no true bone is formed. The matrix contains some scattered fibres.

The cartilages of the nose, thyroid, cricoid,

trachea, and bronchi, resemble costal, though for the most part no fibres are to be seen in the matrix.

(*c*) **Articular.**—The cells near the bone are arranged in columns, though irregularly distributed near the surface. The matrix is not prone to calcify.

FIBRO-CARTILAGE.

1. White fibro-cartilage.
2. Yellow fibro-cartilage.

White Fibro-cartilage differs from hyaline in having the matrix occupied by fibres of white fibrous tissue. It is consequently tougher and less elastic. Its microscopic characters resemble white fibrous tissue rather than cartilage, consisting of parallel wavy fibres with a few cartilage cells. It is distributed in the following manner :—

1. *Inter-articular* fibro-cartilages form small pads occupying a movable joint, their surfaces being free and lined by synovial membrane. They greatly assist in deadening the effects of shock. They are present in the temporo-maxillary, sterno-clavicular, acromio-clavicular, inferior radio-ulnar articulations, and also in the knee-joint.

2. *Circumferential*, serving to deepen articular cavities, as in the glenoid cavities of the shoulder and hip-joints.

3. *Connecting*, which serve to connect the surfaces of bones together in immovable joints, and at

the same time to diminish shock—as the intervertebral discs, sacro-iliac synchondrosis.

4. *Lining Bony Grooves*, serving to deepen and render smooth the grooves in which certain tendons work, as the tendons of the peronei, extensors of the thumb.

Also forming the sesamoid cartilages developed in several tendons.

Yellow elastic Fibro-cartilage differs from hyaline in having its matrix pervaded with yellow elastic tissue. It is tougher, more flexible and elastic than the hyaline variety. Microscopical examination of the epiglottis shows a fine network of elastic fibres, with numerous cartilage-cells scattered through its substance. In the external ear the network of elastic fibres are coarser. It forms the Eustachian tube, external ear, epiglottis, and cornicula laryngis.

BONE.

Bone is a tough, hard, white substance, which forms the skeleton of the adult. It is also elastic, as seen in the clavicle and ribs. It consists of two different kinds of material, compact and cancellous tissue. The *compact*, as its name implies, is dense and hard, and forms the outer shell of bone. *Cancellous* tissue occupies the internal parts, and consists of spicules of bone, forming a network, and leaving spaces filled with fatty matters and blood-vessels. The two tissues gradually shade off into

one another, there being no well-marked separation between them. Bone is surrounded by a fibrous membrane, the periosteum, which supports the blood-vessels. Its outer layer is formed of tough fibrous tissue, its inner layers of fine elastic fibres, and in young growing bone of numerous corpuscles and granular matter. The long bones consist of a zone of compact tissue on the surface, an inner zone of cancellated tissue, and a medulla filled with marrow in the centre. The marrow in adults consists largely of fatty matters, with a certain number of nucleated cells resembling leucocytes, extractives, and salts. The red marrow of young bones is formed largely of cellular elements and but little fat.

Chemical composition:—

Animal matter . .	33·3
Mineral ,, . .	66·7

The animal matter is converted by boiling into gelatin.

The mineral consists of calcic phosphate, calcic carb., magnesia, sodium, fluorides and chlorides.

Minute Structure.

1. Haversian canals.
2. Lacunæ, canaliculi, osteo-blasts.
3. Lamellæ and perforating fibres.

On examining with a low power a thin transverse section of a long bone (which has been ground extremely thin or decalcified and a section cut), a

number of dark spots, or round apertures, will be seen, from $\frac{1}{200}$th to $\frac{1}{1000}$th of an inch in diameter. They are transparent or dark, according as the bone has been prepared by cutting or grinding. They are the apertures seen in section of the Haversian canals, and are occupied by blood-vessels. The lacunæ will be seen as small, elongated, dark bodies arranged concentrically around the Haversian canals, and on examining with a higher power, will be seen to have numerous fine lines, in reality fine tubes or pores, radiating from them: these are the canaliculi. The lacunæ are small spaces occupied by a nuclear cell, called an osteo-blast, which influences the nutritive processes going on in the bone. The canaliculi communicate, on the one hand, with the Haversian canals, and, on the other, with the lacunæ, and are the means of conveying nutritive material from the blood-vessels to the osteo-blasts. In addition to the lacunæ, numerous concentric rings will be seen surrounding each aperture of the Haversian canals. These rings are occasioned by the transverse section of cylinders or layers of bony tissue surrounding the Haversian canals. In addition to the lamellæ around the canals, there are other lamellæ arranged concentrically around the medullary cavity of the bone. If a very thin shred of a lamella be examined by a high power, it will be seen to consist of an exceedingly fine intersection of fibres, which

cross one another obliquely, and cannot be readily teased out. The lamellæ also exhibit numerous perforations, one set corresponding to the canaliculi, another set, larger and fewer in number, corresponding to the *perforating* fibres which piece adjacent lamellæ in perpendicular and oblique directions, and bolt them together.

Ossification in Membrane.—The roof of the skull is ossified from membrane, *i.e.* the parietal, greater part of the frontal, part of occipital, sphenoid, and temporal, and some of the smaller bones. The base is formed from cartilage. Growth of bone takes place by the ossification of the inner layer of the periosteum. When the tissue in which ossification is proceeding is examined by a high power, it appears to be made up of fibres and corpuscles, with fine granular uniting matter. The corpuscles are large and granular, with well-marked nuclei. Ossification proceeds by a deposit of lime-salts in the finely granular uniting material surrounding the corpuscles, the spaces occupied by the corpuscles forming the lacunæ, and the blood-vessels imprisoned in a similar manner forming the Haversian canals.

Ossification in Cartilage.—In a long bone ossification begins in the centre, and afterwards separate centres appear, forming the epiphyses which subsequently join the shaft.

On examining a longitudinal section of bone undergoing ossification, it will be found that the

first indication of the commencing process is, that the cartilage cells, at first scattered irregularly through the matrix, begin to arrange themselves in columns parallel to the long axis of the bone. Blood-vessels shoot up in loops between these columns, and lime-salts are poured out and precipitated in the matrix. As the deposit of lime proceeds it shuts in portions of the columns of cells and forms short fusiform spaces. The cartilage cells imprisoned within the fusiform cavities disappear, and the cavities become lined by corpuscles similar to those seen in intra-membranous ossification. These corpuscles are either descendants of the cartilage cells, or are leucocytes derived from the blood. The first bone formed is very vascular, and consists of fusiform spaces with bony walls, and filled in part with large granular cells. These spaces soon communicate with one another, and a tissue resembling cancellous tissue is produced. Finally, part of this newly-formed tissue disappears to form the medullary cavity, and part remains to form cancellous tissue, while osteo-blasts, or corpuscles, lining the spaces become imbedded in calcified material forming the compact tissue, which is also formed, as the bone grows, by the ossification of the inner layer of the periosteum.

MUSCLE.

There are two varieties of muscular tissue in the body.

I. Striated muscular fibres.
II. Non-striated muscular fibre.

I. **Striated Muscular Fibre** is found in the muscles attached to bone, such as the biceps, diaphragm, masseter, also in muscles of tongue, soft palate, pharynx, larynx, upper part of œsophagus, platysma, sphincter vesicæ, muscles of prostate. For the most part muscles, which are under the control of the will, are striated, though exceptions are found in the constrictors of the pharynx, œsophagus, heart, &c. Striped muscle is of a dull red colour, and marked with longitudinal furrows on its surface.

A voluntary muscle consists of

1. Connective tissue sheath.
2. Fasciculi.
3. Fibres and sarcolemma.
4. Discs, fibrillæ and sarcous elements.

1. **Sheath.**—Each muscle has its sheath of connective tissue which surrounds it and binds the fasciculi together, and is called the perimysium; it sends fine prolongations in between the fibres called the endomysium.

2. **Fasciculi.**—The longitudinal furrows seen on the surface of the muscle, when the sheath is removed, divide the surface into divisions called the fasciculi. These divisions are coarse in the gluteus maximus, deltoid, and other powerful muscles, while others, as the facial muscles, have fine fasciculi.

3. **Fibres.**—The fibres may readily be seen by teasing out a piece of muscle (which has been macerated in alcohol or ammonium bichromate) under a low power. The fibres are prismatic in section, from $\frac{1}{400}$ to $\frac{1}{700}$ in. diameter, and are marked transversely with dark striæ, close together, and at regular intervals.

Sarcolemma.—The fibres are surrounded by a delicate homogeneous elastic sheath, which can be readily seen in prepared muscle of frog and water beetle, less readily in man, called the sarcolemma; under favourable circumstances transverse membranous septa will be seen, which are connected with the sarcolemma and cross the fibre in the intervals between the dark striæ, dividing the muscle into compartments (each containing a disc), called Krause's membranes.

4. **Discs.**—If the living muscle of the water beetle (Hydrophilus) be examined under a high power, the appearance of transverse striæ will be seen to be due to alternate dark and clear discs, the former highly refractive, the latter less so. The dark striæ form the contractile discs, the light the interstitial discs, the latter taking no part in the contraction of the muscle. A contractile disc occupies one of the compartments formed by Krause's membranes.

Fibrillæ and Sarcous Elements.—If muscle be examined after death, especially if it has been soaked in alcohol or chromic acid, the fibres will be

seen to be split up longitudinally into smaller fibres or fibrillæ, and these again divide transversely so as to form minute bodies, the sarcous elements of Bowman.

Schäfer has described in the muscle-fibres of the water-beetle the dark cross striæ, or the contractile discs mentioned above, to consist of minute rods arranged side by side in the long axis of the fibre, their ends being enlarged into minute knobs.

Cardiac Muscular Fibre differs from ordinary striated muscle in having very faint cross stripes and no sarcolemma ; the fibres are also branched. If the fibres are acted on by osmic acid, they are seen to consist (in mammals) of oblong nucleated cells, some being forked at their extremities, and joined end to end.

II. **Non-Striated Muscular Fibre** is pale in colour, is not under voluntary control, and consists of bundles of contractile cells. It is found in many parts of the body—walls of stomach and intestines, blood-vessels, trachea, œsophagus, ducts, iris, &c. The cells are elongated or spindle-shaped, with an oblong rod-shaped nucleus. They vary in length, and are $\frac{1}{2000}$ in. to $\frac{1}{3000}$ in. in breadth. The cells are held together by a transparent semi-fluid cement substance.

Properties of Muscular Tissue.

Chemical.—If *living* contractile muscle of frog

be freed from blood, and subjected to compression, or frozen and pounded with snow containing 1 p.c. of salt, a fluid termed *muscle-plasma* is obtained, which, like blood, coagulates into clot and serum. The clot, which is granular and flocculent, is myosin, and the serum contains albuminates, and nitrogenous principles, as kreatine, xanthine, &c., also sarco-lactic acid, inosite, glycogen, and salts. Myosin resembles globulin in many respects; it is converted into syntonin or acid albumen by the action of acids, and into alkali albumen by alkalis. *Dead* muscle contains myosin, which can be dissolved out by a 10 per cent. solution of sodium chloride. Living muscle contains no myosin, but substances which are converted into myosin at the death of the muscle. Living muscle is alkaline or neutral; dead muscle is acid from formation of sarco-lactic acid. Living muscle contains glycogen, which, at its death, is converted into sugar.

2. **Electrical** muscle-currents.—Living muscle, like nerve, is traversed by electrical currents. If a piece of living muscle be placed upon electrodes (non-polarisable, i.e., so arranged as to prevent the electrodes themselves from developing currents when in contact with the muscle), connected with a delicate galvanometer, it will be noticed that an electrical current passes through the galvanometer from the equator or some point on the surface of the muscle to the cut end; the greatest deflection

taking place when the electrodes are placed one at the mid-point of the surface and the other at the cut end. A current will pass in the opposite direction from the cut end to the mid-point in the muscle. The current ceases as the muscle dies.

Contractility.—The characteristic property of living muscle is its irritability, the muscle contracting when a stimulus is applied. If a muscle of a recently killed frog be laid bare, and any form of stimulus applied, such as the electrodes of a battery or coil, a hot wire, a chemical substance, or a mechanical injury, it will be thrown into a state of contraction. The stimulus may be applied to muscle itself, or to a nerve in connection with the muscle.

Both nerve and muscle are irritable; the muscle only is contractile.

If the electrodes of an induction coil be laid on the sciatic nerve of a frog, and a single induction-shock (either making or breaking) be made, the gastrocnemius will give a short sharp contraction. If the muscle be attached to a lever arranged to record its movements on a revolving drum, a curve will be produced, the lever rising during contraction and falling during relaxation. The figure traced is the *muscle curve.* The time occupied in tracing the curve can be measured by a marker in contact with a drum, transmitting the vibrations of a tuning-fork. With a suitable arrangement of the above apparatus, the curve will demonstrate three facts :—

1. The '*latent period*'—i.e., a short time, say $\frac{1}{77}$th second, elapsing after the entrance of the shock into the nerve before the lever begins to rise. This latent period is occupied by (*a*) passage of nervous impulse along nerve, (*b*) certain changes taking place in the muscle itself before it begins to contract. The former varies according to length of nerve, the nerve impulse travelling at the rate in the frog of about 28 metres per second. The latter consists of some molecular changes in the muscle which occupy about $\frac{1}{100}$th second.

2. *A period of contraction.*

3. *A period of relaxation.*

Tetanus. If single induction shocks follow one another slowly, a succession of curves are recorded on the drum. But if they are made to follow quickly, as when produced by the 'magnetic interrupter,' the muscle remains in a constant state of contraction known as tetanus.

Change in Form.—When a muscle contracts, it shortens—that is, its ends come nearer together, while the muscle itself becomes thicker; but there is no change of bulk: what it loses in length, it gains in thickness.

Chemical Changes during Contraction.—(1) Muscle is normally neutral or faintly alkaline; when it contracts it becomes acid, the acidity being due to the formation of sarco-lactic acid. (2) Carbonic acid is set free, not accompanied by a corre-

sponding consumption of oxygen. Probably some complex body splits up, producing these two acids. (3) Oxygen is used up. Living muscle is constantly consuming oxygen, but more carbonic acid appears than can be accounted for by oxygen used. Other changes doubtless take place, of which little is known.

Negative Variation of Nerve Current.—Whenever a muscle contracts, a change takes place in its electrical current. If, when a muscle at rest, arranged so as to show its normal current, be made to contract or enter into a state of tetanus, the normal current will undergo diminution during the contraction. By refined methods it has been shown that the negative variation occurs during the 'latent period' of stimulation.

Production of Heat during Contraction.—Venous blood coming from an active muscle is warmer than blood from muscle in state of rest. The gastrocnemius of frog shows an increase of about one-tenth of a degree C. for each contraction. The heat developed depends to some extent on the work done.

Production of Sound during Contraction.—A sound is emitted from a muscle during contraction. By placing the ear over a contracting muscle a deep-toned sound will be heard.

Elasticity of Muscle.—Living muscle is elastic; its elasticity is small, but very perfect. The muscle

will elongate easily under the influence of weights, and will return on their removal to its former length.

Rigor Mortis.—Muscle on dying becomes rigid, but is again relaxed when putrefaction commences. Its tonicety has disappeared, so that on section it will not retract. It cannot readily be extended, and when extended does not return to its normal length. It has lost its translucent appearance, and become opaque; its nerve currents have disappeared.

The chemical changes consist in the formation of myosin, sarcolactic and carbonic acids. In the human corpse rigor mortis sets in from seven to twenty-four hours after death, and lasts from twenty-four hours to several days. As a rule, when it comes on slowly it lasts long. It first affects the muscles of neck and jaw, then the trunk, upper extremities, and lower limbs. In exhaustion of muscular power prior to death, as in animals hunted to death, or soldiers killed late in an engagement, rigor mortis sets in very rapidly.

Effects of Muscular Exercise.

1. **Circulation.**—The increased work performed by the muscles will require an increased activity on the part of the heart to supply them with an adequate quantity of arterial blood. The number of beats of the heart are increased. The muscular contraction will also favour the return of blood to the heart by compressing the veins.

2. **Respiration.**—The unusual consumption of O by the contracting muscles will stimulate the respiratory centres, and the number of respirations will be increased. An increased amount of O will be absorbed, and more CO_2 excreted.

3. **Temperature.**—The increased consumption of O and friction of the contracting muscles will tend to raise the temperature, but this will be more or less neutralised by the cooling effects of the evaporation of the increased perspiration.

4. **Skin.**—The capillary arteries supplying the skin will be dilated, and more perspiration will be poured out, which will tend to accumulate on the surface of the skin.

5. **Urinary.**—The watery constituents of the urine will probably be lessened in consequence of the increased escape of fluid at the skin. Urea will be slightly increased, though not in large proportion. The increase of urea will rather represent the wear and tear of the tissues than the waste product of the combustion of nitrogenous matter.

6. **Remote.**—The increased loss of water will tend to cause thirst, and the increased combustion of hydro-carbons and wear and tear of tissue will tend to increase the appetite for food. Long-continued or regular exercise will prevent the accumulation of fat, and in moderation will improve the tone of the system, and will tend to increase the development of muscle.

SKIN

Consists of—

1. Epidermis or dermis.
2. Dermis, corium or cutis vera.
3. Sweat glands, nails, hairs, and sebaceous glands.

1. **The Epidermis** forms a protective covering over the surface of the body. It consists of a stratified layer of epithelial cells. The cells nearest the surface are flat and dry, those in the deepest layers are round and moist, while those occupying an intermediate position become more and more flattened as they approach the surface. The term *horny layer* is given to the layer of cells nearest the surface, while the deep layer of round cells is called the *rete mucosum.* Pigment, when present in the skin, is contained in the rete mucosum. The cells of the horny layer will not stain with carmine or logwood, but are coloured by picric acid; the cells of the deep layer are readily tinted by ordinary staining fluids. The epidermis is evascular, contains no nerves, and is perforated by the ducts of the sweat glands.

2. **The Dermis,** or true skin, is made up of an interlacing network of connective tissue, formed of white fibrous tissue, yellow elastic tissue, corpuscles, vessels, and nerves. In some parts of the body, as in the skin of the scrotum, perineum,

penis, the cutis vera contains unstriated muscular fibres. There are also small muscular fibres in connection with the hair follicles. Beneath the skin the subcutaneous tissues contain abundant adipose tissue. Numerous fine ridges are seen on the surface of the skin of the palm of the hand and sole of the foot. The ridges are caused by rows of little elevations of the cutis vera termed *papillæ*. These little eminences are more or less conical, or sometimes club-shaped; they may be compound, and contain a capillary loop, nerve, and touch corpuscle; they project into the epidermis, and by raising it up as it were, form a ridge on the surface of the skin. They serve to increase the sensitiveness of the part, lodging a touch corpuscle in a favourable position for receiving sensations of touch.

Sweat Glands are situated in the subcutaneous tissue, and consist of a fine tube which forms the duct, its blind extremity being coiled up like a ball, and surrounded by a plexus of capillaries to form the gland. The duct is twisted like a corkscrew, and widens slightly at the orifice. The gland is lined by secreting epithelium. Each tube, if uncoiled, is said to measure $\frac{1}{4}$ inch.

Nails.—The nail consists of a root, body, and lunula. The root is that part of the nail which is covered by the skin, the body the external part, and the lunula is the whitish portion of the body near the root where the skin beneath is less vascular.

Structure.—The nail closely resembles the epidermis, and is, in fact, a modification of that structure, consisting of hard and thin layers of cells on the surface, and round moist cells beneath, corresponding to the rete mucosum.

Posteriorly the nail fits into a groove which lodges its root. The part of the cutis vera to which the nail is attached is called the matrix, and is provided with large papillæ.

Hairs,—consist of shaft and root. The shaft of the hair is cylindrical, and covered with a layer of imbricated scales, arranged with their edges upwards. The substance of the hair consists of fibres, or elongated fusiform cells, in which nuclei may be discovered. There are also present in some hairs small air spaces, or lacunæ. In the coarser hair of the body there is a medulla, or pith, which is occupied by small angular cells and fine fat granules. The root of the hair swells out into a knob, and fits into a recess in the skin, called a hair follicle.

The follicle consists of two coats, an outer, or dermic coat, continuous with the corium, and an inner, continuous with the epidermis, and called the root sheath. The *outer*, or *dermic coat*, is formed of connective tissue, and is supplied by numerous vessels and nerves. It is separated from the root sheath by a homogeneous membrane. The *inner*, or *epidermic coat*, comes away when the hair is pulled out, and hence is called the root

sheath. It is made of two layers, the outer root sheath and inner root sheath. The *outer root sheath* corresponds with the rete mucosum, and is thicker than the inner, and is composed of large round cells. The *inner root sheath* corresponds with the horny layer. It is composed of flattened cells. The deeper cells of the inner root sheath form what is called Huxley's layer.

The bulbous root of the hair fits on to a papilla, which is very large in the tactile nasal hairs of the cat. Small bundles of involuntary muscular fibres connect the corium with the root of the hair, so that in contracting they elevate the hair.

The Sebaceous Glands consist of a small duct, which opens into the hair follicle, and is connected by its other end with a cluster of saccules lined with epithelium, which secrete fatty matters.

The Perspiration is a clear acid colourless fluid with a peculiar odour. It contains nearly 2 per cent. of solid matter. The amount must vary very considerably according to season, exercise taken, or fluid ingested. On an average there is about thirty ounces lost by the skin, though under exceptional circumstances the same amount might be lost in an hour. The sweat is constantly being exhaled from the body, either insensibly, or it collects in drops upon the skin, which gradually evaporate. The sweats consist of—

1. Salts,
2. Fatty acids,
3. Fats,
4. Nitrogenous bodies.

The salts consists of sodium and potassium chlorides. The acids of acetic, butyric, formic, &c.

The nitrogenous bodies include urea, ammonia, and other more complex bodies. It is uncertain how much urea is excreted by the skin, if, indeed, any is, under normal circumstances.

According to some, 100 grs. of nitrogenous material are thrown off by the skin daily. A certain quantity of CO_2 is given off by the skin, though probably small; being $\frac{1}{40}$th of that given off from the lungs. Rabbits which have been covered with an impermeable varnish soon die. They become quickly cool, and have albuminuria. These effects are probably due to the absorption or non-excretion of the sweat, and to rapid loss of heat from dilatation of the cutaneous vessels.

Absorption through the skin may take place under exceptional circumstances. Mercury, arsenic, and many other reagents are absorbed by the skin when rubbed on the surface. The skin will absorb iodine if exposed to steam impregnated with that reagent, the iodine being again excreted by the urine.

SECTION III.

THE BLOOD.

The blood, as it exists in the living body, is a red homogeneous alkaline fluid, of saltish taste and faint odour, and S. G. 1052–1058. It consists of minute solid bodies, the corpuscles, floating in a liquid—the liq. sanguinis.

When drawn from the blood-vessels coagulation takes place, fibrin is formed, and a separation takes place into clot and serum.

$$\text{Blood in living body}\begin{cases}\text{Liq. sanguinis}\begin{cases}\text{water}\\ \text{salts}\\ \text{albumen}\\ \text{elements of fibrin}\end{cases}\\ \text{Corpuscles}\end{cases}$$

$$\text{Coagulated blood}\begin{cases}\text{Liq. sanguinis}\begin{cases}\left.\begin{array}{l}\text{water}\\ \text{salts}\\ \text{albumen}\end{array}\right\}\text{serum}\\ \text{elements of fibrin}\end{cases}\\ \text{Corpuscles}\end{cases}\text{clot}$$

If the blood, as it flows from the blood-vessels, be stirred with a stick, so as rapidly to cause coagulation, we have—

$$\text{Blood}\begin{cases}\text{Liq. sanguinis}\begin{cases}\text{elements of fibrin} \quad \text{Fibrin}\\ \left.\begin{array}{l}\text{albumen}\\ \text{salts}\\ \text{water}\end{array}\right\}\text{Defibrinated blood}\end{cases}\\ \text{Corpuscles}\end{cases}$$

RED CORPUSCLES.—Human red corpuscles are circular biconcave discs of $\frac{1}{3200}$ in. in diameter. Examined singly with a power of 300 they are of a yellowish colour, and present a light transparent centre surrounded by an opaque rim or *vice versâ*, according as the centre or edge is brought into focus. Examined edgeways their biconcave shape will be readily seen. They have no nucleus or limiting membrane. The red corpuscles of mammals resemble those of man; the elephant has the largest, $\frac{1}{2700}$ in.; the musk deer the smallest, $\frac{1}{6300}$ in. They are oval in the camel tribe. In birds, reptiles, amphibians, and fishes, the coloured corpuscles are elliptical discs, the proteus having the largest, $\frac{1}{400}$ in. by $\frac{1}{700}$ in; they have also a prominent central nucleus. The red corpuscles are soft in structure, elastic, and while pressure changes their shape, they readily regain it. When examined shortly after being drawn from the vessels, they adhere together by their surfaces, and appear like rolls of coins.

Effects of Reagents—Salt Solution.—When human blood is diluted with $\frac{3}{4}$ per cent. salt solution, serum, or other saline solution, the red corpuscles lose their sharp circular outline, minute prominences appear on the surface, and they assume an appearance termed '*horsechestnut-shaped*' from their resemblance to the prickly fruit of the horsechestnut.

Carbonic Acid.—If the horsechestnut-shaped corpuscles be treated with carbonic acid gas, they

again become smooth, though they do not regain their original biconcave form, but are more or less concavo-convex.

Tannic Acid.—If the horsechestnut-shaped corpuscles are treated with 2 per cent. tannic acid, their hæmoglobin separates itself from the stroma of the corpuscle, and is extruded in a drop-like mass.

Boracic Acid.— In newt's blood, treated with 2 per cent. boracic acid, the nucleus become of deeper colour at the expense of the disc, and a fine network of fibrils are displayed, which pervades both disc and nucleus. This fine network is occupied normally by hæmoglobin and a homogeneous interstitial substance.

Water makes the corpuscles swell up and lose their hæmoglobin, their outline becoming very faint.

The red corpuscles contain—

1. Hæmoglobin,
2. Globulin,
3. Salts,
4. Gases,
5. Water.

Hæmoglobin contains C.H.O.N.S.Fe., and forms 90 per cent. of red corpuscles. It is soluble in water and serum, crystallising in man and many mammals in elongated rhombic prisms, octahedral in the guinea-pig, and hexagonal in the squirrel.

It can be obtained in crystals from the guinea-pig, rat, or mouse, but with difficulty from the blood of sheep, ox, or pig.

Preparation.—The hæmoglobin is made to leave the corpuscles by shaking with ether or by alternately freezing and thawing the blood. The blood is thus rendered translucent or 'laky'; one quarter of its bulk of alcohol is added, and it is placed in a temperature of 0°C to crystallise.

Hæmoglobin exists in the human blood in two forms, one in loose combination with oxygen—oxy-hæmoglobin—and the other as reduced hæmoglobin. If oxy-hæmoglobin be acted upon in solution with a reducing agent, as an alkaline solution of ferrous sulphate and tartaric acid, it is reduced and becomes of a purplish red colour. Oxy-hæmoglobin gives in the spectrum two narrow dark bands in the green, reduced hæmoglobin a single broad dark band intermediate in position between the two. Hæmoglobin readily decomposes, forming hæmatin and globulin. Hæmatin forms with HCl a compound called hæmin, which crystallises in minute rhombic prisms. Hæmoglobin gives a characteristic blue colour when treated with tr. guaiaci and solution of peroxide of hydrogen.

2. **Globulin** or **Paroglobulin.** See *Coagulation.*

3. **Salts.**—These amount to 1 per cent. of the dried solids, the principal salts being those of potassium and phosphates.

4. **Gases.**—Oxygen loosely combined with the hæmoglobin. Nitrogen in small quantity. The existence of carbonic acid gas in the corpuscles is uncertain; by far the greater part exists in the serum.

5. Water forms 56·5 per cent. of the corpuscles.

Origin of Red Corpuscles.—In the *embryo*—1. From cells in the vascular area of mesoblast. 2. By division. 3. From white corpuscles. *Adult.*—From white corpuscles, transitional forms exist in medulla of bone and spleen.

Fate of Red Corpuscles.—Probably broken up in spleen. Hæmoglobin probably forms bile-pigments.

White Corpuscles or Leucocytes.—The white corpuscles in human blood are spheroidal, finely granular masses of $\frac{1}{2500}$ inch in diameter. Some of them are less, being smaller than the red corpuscles. They have no cell wall, and their substance consists of protoplasm. According to Heitzmann, their granular appearance is due to a fine intercellular network having small dots at the intersections of the network. In the meshes of the network there is a hyaline substance. They possess one or two nuclei, which are readily brought out by acetic acid. When examined in a fresh state, especially if placed on warm stage, they exhibit spontaneous change of shape like the amœbæ, these movements being termed amœboid. The movements consist in

a protrusion of processes of protoplasm, which are retracted and other processes protruded.

Both in human and newt's blood there are some colourless corpuscles which contain coarser granules than others; these are called *granular corpuscles.* The white corpuscles will take up coloured foreign particles, as vermilion. They are found in various tissues of the body, as in the meshes of the retiform tissue of lymphatic glands, tonsils, solitary glands, &c. In inflammation they pass through the walls of the capillaries into the tissues. They are present in the blood in the proportion of 1 per 300 red corpuscles after a meal, and 1 per 800 during fasting; they are much more numerous in some diseases, as in leucocythæmia.

Composition :—

1. Several albuminous substances.
2. Lecithin and glycogen.
3. Salts mainly potassium and phosphates.
4. Water.

Origin.—Probably from the lymphoid tissues of the body, i.e., lymphatic glands, solitary glands, spleen, &c., by division of the leucocytes existing there. The thoracic duct and lymphatics are constantly pouring white cells into the blood, derived from the mesenteric and other lymphatic glands.

Fate.—They are converted into red corpuscles.

During inflammation they pass through the capillary walls, and are converted into pus-cells; it is also probable they are utilised in other ways than in forming pus, possibly being converted into the cell-elements of new tissues, or taking the place of worn-out cells throughout the body.

Liq. sanguinis is a clear yellow alkaline fluid in which the corpuscles float. It may be obtained by allowing the slowly coagulable blood of the horse to stand in a tall vessel surrounded by ice. The temperature of 0° C. prevents coagulation, the corpuscles subside, and the clear fluid may be removed by pipette. Its composition may be described as serum plus the elements of fibrin.

Serum.—When blood has coagulated, and the clot separated, a thin yellow transparent alkaline fluid is left of S.G. 1028.

It consists of—

1. Albumin.
2. Paraglobulin.
3. Extractives.
4. Fatty matters.
5. Salts.
6. Water and gases.

1. **Albumin** exists in combination with the sodium as an albuminate. It is in the form of serum-albumen, differing from egg-albumen in not being coagulated by ether. On boiling the serum, the

albumen coagulates ; the fluid, after being deprived of its albumen, is called *serosity.*

2. **Paraglobulin,** one of the fibrin-factors, is present, all the fibrinogen disappearing during coagulation.

3. **Extractives** include kreatin, kreatinin, urea, uric acid, and traces of grape sugar.

4. **Fatty Matters** in minute division, and combined with sodium as soaps.

5. **Salts,** principally sodium salts, in combination with Cl. and CO_2, smaller quantities of potassium and calcium phosphates and sulphates.

6. **Gases.**—CO_2, partly free, and partly in combination with the sodium.

GASES OF THE BLOOD.

In 100 vols. of

	Oxygen.	Carbonic acid.	Nitrogen.
Arterial blood there are	20 vols.	39 vols.	1 or 2 vols.
Venous blood „ „	12 „	46 „	1 or 2 „

measured at 760 mm. and 0° C.

Oxygen.—The greater part of the oxygen of the blood is in loose chemical composition with the hæmoglobin, only a small part is simply dissolved. If water in which oxygen is simply dissolved be subjected to diminished pressure in a mercurial air-pump, the gas begins to be given off immediately the pressure is reduced, and the amount disengaged is proportional to the pressure ; in other words, it

is said to follow Dalton's law. But if arterial blood be submitted in like manner to diminished pressure, no oxygen will be given off till the pressure sinks to $\frac{1}{6}$th of an atmosphere (125 mm.) The gas is then rapidly given off, and the blood becomes dark.

Carbonic Acid.—This gas does not combine with hæmoglobin, but is present in the blood (*a*) dissolved in the serum, (*b*) major part in combination with sodic carbonate, forming a hydro-sodic carbonate. Volume for volume serum yields as much carbonic acid as blood.

Nitrogen.—This gas is simply dissolved in the serum.

COAGULATION OF THE BLOOD.

Blood drawn from a living animal into a beaker first becomes viscid and then is converted into a jelly. This jelly is the same bulk as the previous blood. Finally, the jelly contracts, forming the clot, and a yellow clear liquid, the serum, oozes out. In man blood becomes viscid in two or three minutes, forms a jelly in five or six minutes later, and a few minutes later still the serum begins to appear. In the horse coagulation goes on more slowly, so that the corpuscles have time to sink before the jelly stage is reached ; so that a yellowish stratum is formed on the top, free from red corpuscles, but containing white, called the 'buffy coat.'

This buffy coat appears in human blood in certain inflammatory conditions.

Many circumstances favour or postpone the coagulation of the blood. The principal are

Circumstances favouring Coagulation.

1. Contact with foreign matter,
2. Moderate temperature, 100° to 120° F.,
3. Stasis of blood in the vessels, or injury to the lining membrane.

Circumstances retarding Coagulation.

1. Contact with lining membrane of the blood-vessels.
2. Cold 0° C. indefinitely postpones.
3. Addition of neutral salts, or the caustic alkalis.

The immediate cause of coagulation is the formation of fibrin, of which blood yields about ·2 per cent. Fibrin is formed by the union of two albuminous bodies present in the blood—paraglobulin and fibrinogen A third body, supposed to be of the nature of a ferment, is essential, or at any rate favours the process.

Fibrin.—This substance may be obtained by stirring some freshly-drawn blood with a stick or bundle of twigs. It is a white stringy body, insoluble in water or alcohol, soluble in alkalies,

lactic, phosphoric and acetic acids. H.Cl converts it into syntonin.

Paraglobulin may be obtained from serum or diluted liq. sanguinis, by passing through it a stream of CO_2 or saturating it with NaCl. It is thrown down as a granular white precipitate.

Fibrinogen may be obtained in a similar manner by passing CO_2 through hydrocele or pericardial fluid, or saturating with NaCl.

The Ferment is obtained by adding defibrinated blood to twenty times its bulk of alcohol; a precipitate of albuminous bodies with the ferment is thrown down. Distilled water dissolves out the latter, and if added to a solution containing fibrinogen and paraglobulin, coagulation quickly ensues.

Contact with foreign matter quickly determines coagulation, while contact with the endothelium of the blood-vessels exercises a restraining influence. If the jugular vein of a horse be ligatured at both ends and cut out, the blood will remain fluid for one or two days, but will clot on being withdrawn. Blood will remain fluid for several days in the excised heart of the turtle. Horse's blood allowed to stand surrounded by ice will remain fluid indefinitely. Blood drawn into a saturated solution of sodic phosphate will remain fluid, but will clot if diluted. The share taken by the corpuscles in coagulation is uncertain. Fluids containing white

corpuscles clot more firmly and quickly than those containing red only.

Amount of Blood in Body.—Probably about $\frac{1}{13}$th of the body-weight as estimated by the hæmoglobin in the blood.

SECTION IV.

THE CIRCULATION.

THE circulation is carried on by means of the—

1. **Heart**, beating about seventy per minute, alternately receiving blood from the venous system, and discharging it into the pulmonary artery and aorta.

2. **Arteries**, with elastic and muscular walls, forming channels for the blood to the system, assisting the heart in maintaining the circulation, and regulating the supply of blood to different parts.

3. **Capillaries.**—Canals of minute calibre, with thin permeable elastic walls, allowing both liq. sanguinis and white corpuscles to pass through their walls into the surrounding tissues.

4. **Veins**, forming channels back to the heart, provided with muscular walls and valves, and being sufficiently capacious to hold the total blood of the body.

THE HEART.

THE heart consists of four chambers with contractile walls, situated in the chest, and surrounded

by a fibro-serous sac—the pericardium in which it works.

The Pericardium.—This membranous sac is attached below to the diaphragm, while its upper and narrower part surrounds and is attached to the great vessels connected with the base of the heart. It consists of an external fibrous layer, and an internal serous sac. The *fibrous* layer is a tough dense membrane, attached below to the central tendon and muscular fibres of the diaphragm; above it is attached to the great vessels, and is continuous with their external coats. The *serous* covering consists of a parietal layer, which is united to the inner surface of the fibrous layer and a visceral which is reflected round the great vessels enclosing the aorta and pulmonary artery in a common sheath. In structure the serous layer resembles other serous membranes.

General Description of the Heart.—In form, the heart resembles a cone, its *base* being directed upwards, backwards, and to the right, its apex downwards, forwards, and to the left. In part it is covered by the lungs, especially during inspiration. Its *apex* beat is felt at the fifth intercostal space, two inches below the nipple, and one to the inner side of left nipple line. In order to map the outline of the heart on the chest wall, define the *base* by drawing a transverse line across the sternum corresponding with the upper border of third costal

cartilages, continuing it $\frac{1}{2}$ in. to right of sternum, and 1 in. to left. *Lower border.*—Draw a line from apex beat through sterno-xiphoid articulation to right edge of sternum. *Right border.*—Continue last line with an outward curve to join right end of base line. *Left border.*—Draw a line curving to left (inside nipple) from apex beat to left end of base line. (*Holden.*)

Cavities of Heart.—The heart contains four chambers, two auricles and two ventricles.

The Right Auricle receives the blood from the superior and inferior venæ cavæ at its upper and lower posterior angles. The septum between the two auricles forms the posterior wall, and presents the *fossa ovalis* (the remains of the *foramen ovale*), which is surrounded by a border (except below), the *annulus ovalis.* Between the two orifices of the venæ cavæ is the *tubercle* of *Lower*, and in front of the opening of the inferior vena cava is the *Eustachian valve.* The *coronary vein* opens into the auricle between the inferior cava and auricular ventricular opening, and is guarded by the *valve* of *Thebesius.* The auricular appendix is a tongue-shaped appendage, which projects from the anterior angle, and covers the root of the aorta. The cavity of the auricle is smooth, except that of the auricular appendix, which presents the muscular bands called *musculi pectinati.* The openings into the right auricle are the following:—1. Openings of venæ

cavæ; 2. auriculo-ventricular opening; 3. orifice of coronary sinus; 4. openings of one or two small veins of right ventricle; 5. foramina Thebesii, which are small depressions, some of them transmitting minute veins.

The Right Ventricle forms the right border and chief part of anterior surface of heart. At its base are two orifices guarded by valves, the *auriculo-ventricular* and the *pulmonary artery*. The inner surface presents muscular elevations termed *columnæ carneæ*, some of which are attached by their extremities to the wall of the ventricle, others in their whole length, while a third set are connected by their bases to the ventricular wall, and are connected by their other extremities to the segments of the tricuspid valves, by means of the *chordæ tendinæ*.

The Left Auricle is situated at the posterior part of the base of the heart. It receives two pulmonary veins on each side, and opens into the left auricle through the mitral valve. The interior of the left auricle is smooth like the right, its appendix presenting musculi pectinati.

The Left Ventricle forms the left margin of the heart, the greater part of the posterior, and a small part of the anterior surface. Its walls are some three times as thick as the right ventricle, its musculi papillares are larger, and the chordæ stronger. Like the right ventricle, it has two orifices, *auri-*

culo-ventricular, guarded by the mitral, and the *aortic*, guarded by the *semilunar valves*.

Endocardium.—The internal membrane lining the heart closely resembles the lining membrane of the arteries. It consists of a single layer of tessellated epithelium, with a connective tissue layer beneath.

Valves of Heart.—The *mitral* and *tricuspid* valves are situated at the auriculo-ventricular orifices, and prevent the passage of blood into the auricle during the ventricular systole. They consist of flaps or cusps, two in the mitral, and three in the tricuspid, connected by their bases to the auriculo-ventricular orifices; their free margins and lower surfaces give attachment to the chordæ tendinæ which connect them with the musculi papillares. They are formed of a duplicature of the lining membrane of the heart, strengthened by connective tissue. During the ventricular systole, the pressure of the blood in the ventricles presses their free edges or rather their marginal surfaces together, the musculi papillares regulating the tension of the chords and preventing the valves from becoming retroverted into the auricles.

The *semilunar valves* guard the aortic and pulmonary openings. They consist of three semicircular folds attached by their convex margin to the wall of the artery at its junction with the ventricle, and are formed of a reduplication of the

lining membrane strengthened by fibrous tissue. In the centre of each free margin is a little nodule, the corpus Arantii, the three meeting in the centre when the valves are closed. On each side of the corpora Arantii is a thin semilunar marginal surface, where the fibrous tissue is absent, called the lunula, these surfaces come in contact when the valves close. After the systole of the ventricles, the tension of blood in the aorta and pulmonary artery close the valves by distending them and pressing the marginal surfaces together. The semilunar valves during the ventricular systole are pressed back against the walls of the aorta, and hence, according to Brücke, prevent the filling of the coronary arteries which arise from the sinus of Valsalva during the ventricular systole, the coronary arteries being filled after the closure of the valves and during the diastole of the ventricle.

Sounds of the Heart.—*First sound*—Best heard at the apex beat. It is synchronous with the ventricular systole, commencing immediately the ventricle begins to contract, but ceases before its completion. It is louder, longer, duller, than the second sound. Various explanations have been given as to its cause, none of them are entirely satisfactory.

1. Closure of auriculo-ventricular valves.
2. Muscular sound of contraction of ventricles.
3. Cardiac impulse against chest wall.

The *second sound* is short and sharp, is heard best at junction of 3rd costal cartilage with sternum, and corresponds to the closure of the semilunar valves. Between the first and second sounds the pause is very short, but between the second and succeeding first the pause is longer, and is about equal in duration to the time occupied by the first and second sounds together. The sounds have been likened to the pronunciation of the syllables lŭbb, dŭp.

A Cardiac Revolution.—A complete cardiac cycle includes the entrance of blood into the auricles, the systole of the latter filling the ventricles, and the ventricular systole propelling the blood into the pulmonary artery and aorta. During the pause after the contraction of the ventricles, the venæ cavæ and pulmonary veins are pouring blood into the auricles. The auricular systole commences in the muscular fibres surrounding the great veins, the contraction running through vessels and auricles in a peristaltic wave, emptying the contents of the vessels into auricle, and then emptying the auricle itself, the appendix being the last part to contract, the ventricles becoming filled. Regurgitation into the great veins is hindered by—

(1) Peristaltic contraction of muscular walls of veins.

(2) Aspirating power of thorax during inspiration.

(3) Valves at junction of subclavian and internal jugular veins.

Regurgitation into the coronary sinus is prevented by valve of Thebesius. Then follows immediately the ventricular systole; the ventricles become tense and hard, shorter and thicker; the heart twisting on its long axis strikes the chest wall, and ejects the contents of the ventricles (about 5 oz.) into the pulmonary artery and aorta. At the commencement of the v. systole the auriculo-ventricular valves close, and the semilunar open; and at the termination of the systole the semilunar close and auriculo-ventricular open. The time occupied by a complete beat is slightly over a second. It will be divided in the following manner:—

Contraction of auricles	$= \frac{1}{5}$ sec.
Dilatation of auricles	$= \frac{4}{5}$ sec.
Contraction of ventricles	$= \frac{2}{5}$ sec.
Dilatation of ventricles	$= \frac{3}{5}$ sec.

or,

Auricular systole	$= \frac{1}{5}$ sec.
Ventricular systole	$= \frac{2}{5}$ sec.
Pause	$= \frac{2}{5}$ sec.

Endocardial Pressure.—Goltz and Gaule found the maximum pressure in the left ventricle of a dog amount to 140 mm. of mercury, 60 mm. in the right ventricle, and 20 mm. in right auricle. Im-

mediately after the systole a negative pressure of -52 to -20 mm. was observed in the left ventricle, in the right ventricle about -17 mm., and in the right auricle -12 to -7 mm. While to some extent this negative pressure is due to the aspirating power of the thorax during inspiration; yet, as a considerable negative pressure is observed after the chest is opened, it would appear that the suction-power or active dilatation of the ventricles, and in a lesser degree the auricles, is of considerable service in carrying on the venous circulation.

THE ARTERIES.

Structure.—The arteries have three coats—

1. Internal $\begin{cases}\text{Epithelial.}\\ \text{Sub-epithelial.}\\ \text{Elastic.}\end{cases}$
2. Middle $\begin{cases}\text{Muscular.}\\ \text{Elastic.}\end{cases}$
3. External—Connective tissue.

1. **Internal.**—This coat may be readily stripped off the inner surface of the artery as a transparent, colourless, elastic and brittle membrane. It is formed of—

(*a*) An epithelial layer, consisting of a single layer of thin, elongated cells, with nuclei.

(*b*) Sub-epithelial layer, composed of branching corpuscles lying in cell-spaces of homogeneous connective tissue.

(*c*) Elastic layer, consisting of a fine membrane marked with interlacing network of fibres and perforated with round openings, and termed fenestrated membrane of Henle.

2. **Middle or Muscular.**—In the small and medium-sized arteries the middle coat consists of pure non-striated muscular fibre, arranged transversely round the artery with only a slight admixture of elastic tissue. In the larger arteries yellow elastic fibre predominates, and, indeed, the aorta consists of nearly pure yellow elastic tissue.

3. **External coat,** or tunica adventitia, consists of fine connective tissue.

Circulation in the Arteries.—At each ventricular systole some 5 oz. of blood are forced into an already overfilled aorta and arterial system; the effect of this being (1) to increase the tension in the arterial system and distend the elastic walls of the aorta and large arteries, (2) to send a wave impulse along the blood in the arteries which is gradually lost before reaching the capillaries and which can be felt in the radial as the pulse. If the arteries were rigid tubes, the intermittent action of the heart would cause an intermittent flow of blood from the arteries to the capillaries. The effect of the ventricular systole is to distend the walls of the aorta, to store up force during the systole to be utilised in continuing the circulation during diastole, the recoil of the elastic walls assisting to convert the inter-

mittent blood stream into a continuous one. If a large vessel as the carotid is divided, an intermittent stream of blood flows out, but a wound of a small artery yields a steady stream.

Arterial pressure.—The pressure of blood in the arteries is measured by connecting the carotid artery of rabbit or dog with a U-shaped tube containing mercury. If a float on the mercury be made to carry a small camel's-hair brush or pen, the oscillations of the mercury caused by the varying tension in the blood-vessels can be recorded by the brush or pen writing on a revolving surface. Such an arrangement is called a kymograph. The pressure in the arteries undergoes variations which correspond (1) with each systole of the left ventricle, (2) with the movements of respiration. The average pressure of the blood in the large arteries is greater than in the small.

The pressure in the carotid of man probably amounts to about 150–200 mm. (6–8 in.), in the aorta 250 mm. (9·8 in.), and in the brachial 110–120 mm. (4·3–4·7 in.) of mercury.

Velocity of the Flow.—The rate of movement of the blood in the arteries has been measured principally in the carotids of the horse, dog, and rabbit. In the horse Volkmann found the velocity to be 300 mm. per sec. in the carotid, 165 mm. in the maxillary, and 56 mm. in the metatarsal. Various instruments are employed for this purpose,

the *Stromuhr* of Ludwig and the *Hœmatachometer* of Vierordt being the principal. In order to measure the time occupied by the circulation of any portion of blood, ferrocyanide of potassium is injected into the jugular vein, and the blood from the peripheral end of the same vein tested from time to time. In this way a complete circulation has been found to take place in 15 secs. in the dog, and 23 secs. in the human subject (*Hermann*).

The Pulse.—The impulse or shock caused by the overfilling of the aorta during the ventricular systole is the cause of the pulse. This pulse-wave travels at the rate of 9–10 metres (28–30 ft.) per sec. along the arteries, and is lost at the capillaries. This pulse-wave must be carefully distinguished from the blood-current, the latter travelling only some 300 mm. (12 in.) per sec.; the former stands in the same relation to the moving blood as does a wave on the surface to the current of a slowly flowing river. The duration of the ventricular systole being $\frac{2}{5}$ sec. before the end of the systole, the pulse-wave would have travelled about 12 ft. if that were possible, so that the beginning of each wave is lost at the periphery before the end of it has left the ventricle. The more rigid the arteries the faster the wave travels; the more distensible the more slowly it travels. If the finger be applied to the radial artery, the artery will be felt to expand beneath the finger some 75 times a minute;

under some circumstances the pulse-wave will feel to be double or dicrotic. This dicrotism is shown by the sphygmograph to be constant in health, but is more marked when the tension in the arteries is low, and the arterial walls more distensible than usual, as in febrile conditions of the system. In a sphygmographic tracing, the primary wave is due to the shock given to the blood in the arteries by the systole of the ventricles; the dicrotic wave is probably in part due to the closure of the aortic valves, in part it is a wave of oscillation; the predicrotic wave is also a wave of oscillation. Waves of oscillation are seen when fluid is injected into an elastic tube) as in an artificial scheme of the circulatory apparatus), following the primary wave, and are due to the inertia of the elastic walls and contained fluid.

The Contractility which the arteries possess in virtue of the muscular fibres in their walls fulfils several useful purposes.

(1.) It assists in arresting hæmorrhage when an artery is completely divided.

(2.) Under the influence of the vaso-motor system it regulates the supply of blood to a part.

(3.) It enables the whole vascular system to accommodate itself to the amount of blood in the body.

Frequency of Pulse.—The frequency of the pulse depends upon many various conditions. The

emotions, amount of exercise, state of the digestion, inflammations, fevers, all exert an influence on the pulse rate, through the medullary centres which regulate the contractions of the heart and muscular fibres of the arteries. Other influences may be classified under—

Temperature.—Heat increases, cold slows.

Position of body.—In a sitting position it is faster than in a horizontal position, and in standing up it is faster than when sitting down.

Age.—In the fœtus it is 150–200. In the adult about 75; it increases in old age.

Sex.—It is faster in females than males.

THE CAPILLARIES.

Structure of Capillaries.—The smaller arteries end in a fine network of vessels, which differ in structure from the arteries and veins, their walls containing no muscular elements, but consist of a delicate, transparent wall. Their walls consist of a single layer of elongated epithelium continuous with that of the arteries; the epithelium is rendered apparent by injection of solution of silver nitrate and exposing to light, the reagent darkening the intercellular material and rendering the outline of the cell apparent. Their nuclei can be stained with logwood. In the vessels slightly larger than the capillaries a layer of elongated muscular fibre cells is added.

Size.—Their average size in the human body is about $\frac{1}{3000}$th of an inch, but they differ in different parts of the body. They are comparatively large in the marrow of bone; large also in skin, small in lung, muscle and brain. The network is close in lung and muscle.

Circulation in Capillaries.—The velocity of the blood in the capillaries is very much less than in arteries or veins, being about ·57 mm. to ·75 mm. per second (1·4—1·8 inches per minute). But a very small portion of the capillary system is traversed by any one blood corpuscle. The flow is constant, not intermittent, as in the larger arteries. The red blood corpuscles for the most part travel in the mid-stream, the white corpuscles moving more slowly along the side. The thin capillary walls allow the liq. sanguinis readily to pass through, and so bring the blood in direct contact with the tissues, and also nourish parts by irrigation, in which there are no capillaries, as cartilage and the cornea. Under certain circumstances, as in inflammation, the white corpuscles push through the capillary wall into the tissues; probably this emigration to a smaller extent goes on as a natural process. The movement of blood in the capillaries is dependent upon the action of the heart, modified by the arteries. This constitutes the *vis a tergo.* Some maintain that there is also another motor force called the capillary force. It is asserted that in the

lower classes of animals and in plants there is some power independent of a *vis a tergo*, by which the nutritive fluid moves through the vessels. Cases have occurred in which the heart has been absent in a fœtus during intrauterine life, and yet the circulation must have been maintained. It is supposed that the 'capillary power' supplies the place of a heart up to the period of birth in the acardiac fœtus. It is asserted by Draper that the tissues have an affinity for arterial and a repulsion for venous blood, the opposite holding good in the lungs. The *vis a tergo* derived from the heart is, however, capable of maintaining the circulation in the capillaries, and it is doubtful if any other force, in the higher animals at least, exists.

VEINS.

Distribution.—The veins carry the blood from the capillaries to the heart. They ramify through the body like the arteries, but they are more numerous, anastomose more freely, and are of greater capacity. They usually accompany the arteries; but there are exceptions, as the hepatic, sinuses of the skull, and veins of spinal cord.

Structure.—The veins have thinner walls than the arteries. They have the following coats:—

1. Internal.—This coat closely resembles the inner coat of the arteries.

2. Middle.—This coat is thinner and less mus-

cular, and contains more white fibrous tissue than middle coat of arteries. The muscularity of the middle coat is best marked in the splenic and portal, and least marked in the hepatic part of the inferior vena cava, and subclavian veins.

3. External.—This coat consists of connective tissue and elastic fibres. In certain veins this coat contains a considerable quantity of muscular tissue, as in the abdominal cava, iliac and renal. The striated muscular fibre of the heart is prolonged for some distance on the walls of the pulmonary veins and venæ cavæ. Muscular tissue is wanting in most of the veins of the brain and pia mater, retina, venous sinuses of dura mater, cancellous veins of bone.

Valves.—The valves consist of semilunar folds of lining membrane strengthened by including connective tissue. They consist for the most part of two flaps or pockets, which come in contact by their free margins, and prevent reflux of blood towards the capillaries. The veins of the extremities, neck and scalp have numerous valves, while they are absent for the most part in the deep veins of the abdomen, chest and cranium. Many other veins are destitute of valves. Such are the venæ cavæ, portal, hepatic, renal, uterine, pulmonary and sinuses of skull. There are a few in the intercostal and azygos.

The forces which propel the blood in the veins are—

1. Vis a tergo—heart's action.
2. Vis a fronte—aspiration of the thorax.
3. Muscular contraction.

(1.) The *vis a tergo* or force exerted by the heart in assisting the flow of blood in the venous system is probably not great, the velocity of the blood in the small veins being small.

(2.) The *vis a fronte* or force supplied by the suction action of the chest during inspiration is much more considerable. When an ordinary inspiration is taken, not only is air drawn into the air-passages by the expanding chest, but the blood in the great veins external to the chest is sucked towards the right auricle. This effect is more powerful if a deep inspiration is taken. During an ordinary expiration the sucking action becomes *nil*, while during a powerful expiration, as in blowing or coughing, the expiratory effort obstructs the flow of blood into the chest and causes congestion of the venous system.

(3.) During muscular exercise the veins are compressed by the contracting muscles, the effect being to drive the blood towards the heart, the valves preventing its return towards the capillaries.

The velocity of the blood in the venous system is small when compared with the arteries, though greater in the large veins near the heart than in the smaller veins. It is about 200 mm. per sec. (7 to 8 inches) in the jugular vein of dog. The

pressure in the crural vein of the sheep has been shown to be 11·4 mm of mercury (·4 inches), while in the subclavian it was -1 mm. to -5 mm. during inspiration, the mean pressure being $-\cdot 1$ mm.

INNERVATION OF THE HEART AND ARTERIES.

The nervous mechanism of the heart and arteries consist of—

I. *Heart.*

1. Intrinsic cardiac ganglia.
2. Centres in the medulla — (*a*) inhibitory centre, (*b*) accelerating centre.
3. Inhibitory nerves, *i.e.* vagi.
4. Accelerating nerves, *i.e.* sympathetic.

II. *Arteries.*

1. Vaso-motor centres—medulla, cord, ganglia.
2. Vaso-motor nerves, *i.e.* (*a*) vaso-constrictor, (*b*) vaso-dilator.

I. 1. **Intrinsic Ganglia—Automatic Action.**—If a frog's heart be removed from the body and emptied of blood, it will continue to beat for hours, or even days. It is therefore clear that its action is automatic, and not dependent on any external influence. If the heart is bisected longitudinally, each half will go on beating. If the auricles are separated from the ventricles, both auricles and ventricles

will pulsate; but if divided below the auriculo-ventricular groove, the part with the auricles attached will continue to beat, the ventricular part being motionless. It will be found that the parts which continue to beat contain ganglia. The ganglia are present in the walls of the sinus venosus (Remak's Ganglia), auricular septum, auricular ventricular groove (Bidder's Ganglia).

2. **Extracardiac Centres.**—The inhibitory centre is situated in the medulla, and is constantly in action. It is capable of being influenced by the excitation of various sensory nerves. The accelerating centre is also in the medulla; it is not constantly in action. These centres are largely influenced by afferent nerves from various parts of the body. Thus a ghastly sight, good news, an inflamed pericardium or peritoneum, may profoundly influence the pulsations of the heart through its regulating centres in the medulla.

3. **Inhibitory action of Vagus.**—If the vagus of a frog or rabbit be excited by an interrupted current, the heart's action will become slower, and the blood pressure in the arteries will be diminished; or if the current be strong, it will be arrested in diastole. Section of the vagi is followed by an acceleration of the cardiac beats. If atropin be injected, even a strong current passed along the vagi will not diminish the cardiac beats.

Reflex Inhibition.—If the intestines of a frog

be struck sharply, or the mesenteric nerves stimulated, the heart is brought to a standstill in diastole. If the vagi are divided, or the medulla destroyed, this effect will not take place. The stimulus ascends to the medulla along the mesenteric nerves, and descends to the cardiac ganglia along the vagi. Irritation of other sensory nerves, as the posterior auricular, will have a similar effect.

4. **Accelerator Nerves.** — The sympathetic nerves which pass from the cervical cord to the last cervical and first dorsal ganglia, and from thence to the heart, are called the accelerator nerves. Stimulation of these nerves with the interrupted current causes quickening of the heart's action, and their division renders the heart's action slower. The blood pressure in the arteries is not increased by exciting the accelerators, unless the peripheral resistance is increased by contraction of the arteries. These nerves seem to act by shortening both diastole and systole.

II. **Vaso-motor Centres.**—The principal vaso-motor centre is situated in the medulla. Nothing is known of this centre anatomically, its position having been determined by experiment. Excitation with interrupted current of the medulla of frog will cause the vessels in the web of frog (when seen beneath microscope) to contract. The same result can be witnessed in rabbit by exposing a small artery. Section of cord below medulla causes the vessels to

dilate. The latter experiment shows that the muscular fibre of the arteries is in a continual state of contraction or *tonus*. Various or subsidiary vaso-motor centres are situated in the spinal cord and various ganglia. Besides the vaso-motor or rather vaso-constrictor nerves, there are vaso-inhibitory or vaso-dilators. Such are the chorda tympani to vessels of submaxillary glands, and the nervi erigentes to the arteries supplying arteries of erectile tissue of penis. The vaso-motor centre can be also influenced by various afferent nerves; this may occur through the higher nerve centres, as in blushing; excitation of the central end of various sensory nerves will bring about contraction of arteries; while the vagus contains, especially in its superior laryngeal branch, fibres which excite and also fibres which, when stimulated, lead to inhibition of the vaso-motor centre.

Action of Poisons, &c. on the Circulation.

1. *Nicotine*, *Curare*, *Conia* paralyse the communications of the vagus with the inhibitory ganglia. Stimulation of the vagus is unable to slow the heart; this effect, however, follows stimulation of sinus venosus.

2. *Muscarin* and *Jaborandi* stimulate the whole inhibitory apparatus, and so cause the heart to stop in diastole. Atropia antagonises them.

3. *Calabar bean* also increases the excitability

of the inhibitory mechanism, but will not stop it in diastole.

4. *Atropia*, *Hyoscyamine*, *Daturine* paralyse the whole inhibitory mechanism. Excitation of the vagus and sinus venosus are without effect.

5. *Aconitia*, *Veratria*, *Digitalin*, *Delphinia* and *Antiar* affect the muscular fibre and arrest the heart in powerful systole. (See Hermann's 'Physiology,' translated by Dr. Gamgee.)

SECTION V.

LYMPHATIC SYSTEM.

The lymphatics begin as capillary vessels in almost every tissue of the body, and after passing through one or more of the lymph glands, empty themselves either into the thoracic or right lymphatic duct and thence into venous system.

That portion of the lymphatic system which originates in the mucous membrane of the alimentary canal, takes up the chyle from the intestines during digestion, while it conveys lymph when digestion is not going on.

Lymphatics have not been demonstrated in cartilage, tendon, the eyeball, the placenta, though it is probable they are not wanting.

Structure.—The lymphatic capillaries closely resemble the ordinary capillaries of the body, their walls being formed of a single layer of epithelial cells with a sinuous outline. The lymphatic vessels resemble the veins, their *inner* coat consisting of a single layer of epithelial cells, and a layer of longitudinal elastic fibres. The *middle* coat of circular

muscular fibres mixed with elastic fibres. The *external* of connective tissue.

Some of the lymphatic vessels entirely surround a small artery or vein; the space between the artery and wall of lymphatic is called the *perivascular* space.

They are provided with valves, which are placed so near to one another as to give them a beaded appearance when distended.

Origin.—Two modes of origin—

1. Plexiform.
2. Lacunar.

Plexiform.—Lymphatics begin as a network of capillaries beneath the skin, m.m. of stomach, surface of tendon and diaphragm, and other parts. Sometimes the plexuses are joined by small blind vessels, as in the intestine.

Lacunar.—Lymphatics arise from the irregular spaces which lie between the parts of which an organ is composed. The spaces between the acin or blood-vessels of a gland are lined by an epithelium agreeing in character with that lining the lymphatics. The serous cavities, as the peritoneum, are large spaces from which the lymphatics arise by open mouths (the stomata).

Terminations.—All the lymphatics of the body, sooner or later, empty themselves into the thoracic duct, except those of the right side of the head,

neck, right thorax, right upper extremities, right side of heart, which enter the right lymphatic duct.

The thoracic duct commences opposite the second lumbar vertebra, by means of a dilated portion termed the receptaculum chyli, and terminates in the subclavian in the neck near its junction with the jugular.

Lymphatic Glands are small bodies varying in size from a pea to an almond, placed in the course of the lymphatics. They are collected into groups in the mesentery, anterior and posterior mediastinum, elbow, axilla, neck, groin, and popliteal spaces.

In structure they consist of a capsule of connective tissue and muscular fibre cells, which sends fibrous septa or trabeculæ into the gland substance.

They have a hilus along one border, and are divided into a cortical and medullary portion, the latter occupying the centre of the gland, except at the hilus, where it comes to the surface. The fibrous septa which enter the gland divide it up into alveoli in the cortical portion, but form a closer network in the medullary. The alveoli are occupied by the true gland substance, but are separated from the fibrous septa by a narrow space, which is occupied only by retiform tissue, with nuclei at the intersections of their fibres, and which forms the lymph-channel, or sinus.

The true gland-substance consists of retiform tissue, for the most part non-nucleated, its meshes

being closely packed with leucocytes, and is traversed by blood-vessels.

The afferent lymphatics which enter the gland at its convex border open at once into the lymph-sinus of the cortical part, pass on into the lymph-sinus of the medullary portion, and leave the gland at the hilus. In passing through the gland they come into close relation with the vessels ramifying in the gland substance.

The blood-vessels enter the gland at the hilus, and are distributed through the gland substance; the veins emerge also at the hilus.

Functions.—Liq. sanguinis exudes from the capillary blood-vessels to supply the tissues with materials for their nutrition. The excess of liq. sanguinis thus supplied enters the lymphatic capillaries, passes through the lymph glands into the thoracic duct, and thence into the venous circulation. The liq. sanguinis that has passed out of the capillaries will accumulate in the connective tissue spaces, or lacunæ, from which the lymphatics arise.

The lymphatics which arise in the villi of the small intestine are termed lacteals, and during digestion absorb fatty matters, and to a smaller extent soluble matters and albumen from the contents of the intestine. During the digestion of food, the columnar epithelium covering the villi may be seen to be distended with oil globules (though some observers assert the oil globules pass between the cells),

these globules passing from the epithelium into the retiform tissue, and thence into the fine lacteal present in the villus.

Lymph has been described as blood minus the red corpuscles. It is a yellow alkaline fluid of S.G. 1045 and 6–7 per cent. of solids.

It consists of—

White corpuscles.	Extractives.
Elements of fibrin.	Salts.
Albumen.	Water.

It has been obtained for examination from the thoracic duct during a fasting period, or from some large lymphatic vessel.

Chyle may be described as lymph plus fatty matters. It may be obtained from the thoracic duct during a period of digestion. It is an opaque milky fluid which clots when drawn from the duct: the clot exhibits a pink colour. It contains 8–9 per cent. of solids.

It consists of—

White corpuscles.	Albumen.
Immature red ?	Extractives.
Fatty matters.	Salts.
Elements of fibrin.	Water.

Examined microscopically, white corpuscles are seen in abundance in chyle drawn from the upper part of the thoracic duct. Many of these white

corpuscles are of a reddish colour, and are probably being converted into red.

The fatty matters consist of oil globules of various sizes and finely divided matter of a granular appearance, which forms the molecular basis of chyle. Chyle undergoes changes in its passage from the villi to the thoracic duct; these changes are effected through the agency of the mesenteric glands. They consist in a diminution of the molecular basis and an increase of the white corpuscles and elements of fibrin. Some of the white corpuscles appear to be of a reddish colour.

Movements of the Lymph.

1. *Vis a tergo.* Pressure of blood in the blood-vessels.

2. Contraction of muscular fibres in their walls and in the villi.

3. Compression by muscular action of voluntary muscles.

4. *Vis a fronte.* Aspiration of thorax.

1. If a ligature be applied to the thoracic duct, the chyle will tend to accumulate behind it, or if a tumour compress it the lacteals will become dilated and tortuous. This shows the existence of some *vis a tergo.* The liq. sanguinis leaves the capillaries under considerable pressure, and accumulating in the spaces of the tissues will readily pass into the

lymphatic vessels. Increase of pressure in the arteries causes increased tension in the lymphatics.

2. The muscular fibres in the walls of the lymphatic vessels act after the manner of the lymph-hearts in the frog. The contraction of the muscular fibres of the villi will assist in emptying the contents of the contained lacteal.

3. Contraction of the voluntary muscles will compress the lymphatic vessels in the same way as the veins, driving the lymph forwards, the valves preventing reflux.

4. The enlargement of the chest during inspiration sucks the blood in the large veins towards the heart; the rapid motion of the blood in the subclavian over the orifice of the thoracic duct will tend to make the contents of the duct discharge into the vein, thus supplying the *vis a fronte.*

SECTION VI.

RESPIRATION.

TRACHEA AND BRONCHI.

The walls of the trachea and two bronchi consist of several constituents—

1. Connective tissue.
2. Cartilages.
3. Muscular.
4. Submucous.
5. Mucous membrane.

1. The **Connective Tissue** coat forms an external sheath for the trachea, surrounding and joining together the cartilages.

2. The **Cartilaginous Rings** are incomplete behind, being C-shaped, are 16–20 in number, consist of hyaline cartilage, and serve to maintain a certain amount of rigidity in the walls.

3. The **Muscular Layer** is only present behind, connecting the tips of the cartilages together, and is also present behind in the intervals between the rings. Its fibres belong to the unstriated variety, and serve by their contraction to diminish the diameter of the tube.

4. The **Sub-mucous** coat contains besides connective tissue numerous longitudinal elastic fibres, which may readily be seen on examination from within the tubes. There are also numerous racemose mucous glands.

5. The **Mucous Membrane** is lined by columnar ciliated epithelium, beneath which is situated more or less lymphoid tissue, resembling that of the solitary glands of the intestines. The cilia work towards the outlet of the trachea and help to expel mucus and foreign matter. The mucous membrane and muscular fibres are supplied with branches of the pneumo-gastric nerves.

The two bronchi exactly resemble the trachea in structure, the right having 6 to 8, the left 9 to 12 incomplete cartilaginous rings.

LUNGS (weight, right 24 ozs., left 21 ozs.) The lungs are surrounded by the pleuræ, the smooth surfaces of the latter diminishing friction during the movements of respiration. In shape they are conical, the apex projecting into the root of the neck, the base resting upon the arch of the diaphragm; the inner surface being flattened where the bronchi and vessels enter.

The lungs consist of—

1. Lobes.	4. Infundibula.
2. Lobules.	5. Air-sacs.
3. Bronchi.	6. Blood-vessels and nerves.

1. The **Lobes** are the primary divisions, the right having three, the left two.

2. **Lobules.**—The lobes are divided into *lobules* of various sizes, their outline being most readily seen on the cut surface of fœtal lungs: they are separated by fine connective tissue. In structure they resemble a lung in miniature, having a bronchus, branch of pulmonary artery and vein. The bronchus divides and redivides several times in the lobule, till it terminates in the small dilatations of the infundibula. The branch of the pulmonary artery entering the lobule divides in a similar manner, then breaks up into capillaries surrounding the air-sacs.

3. The **Bronchi**, on entering the lung, divide and redivide, each of the smaller divisions entering a lobule. In structure they resemble the trachea, with some modifications. The *cartilages* in the larger tubes form complete rings, but as the tubes get smaller the cartilages form incomplete rings, consisting of small plates in the walls arranged in a circular manner, and finally are wanting altogether in tubes of $\frac{1}{40}$ in. in diameter. The *muscular fibres* entirely surround the tubes, and may be traced into the finest ramifications. The *elastic fibres* extend to tubes of the smallest size and become continuous with the elastic fibres forming the walls of the infundibula. The ciliated epithelium ceases at the entrance into the infundibula.

4. **Infundibula** are the small sacculated dilatations in which the smallest bronchi terminate. Their walls are formed of elastic tissue, and the many small dilatations of sacculi in their walls form the air-sacs.

5. **Air-sacs** are about $\frac{1}{100}$ in. in diam.; their interior, communicating with the bronchi, is lined by a single layer of squamous epithelium, while their walls are surrounded by a plexus of capillary blood-vessels. The contained air is thus brought into close relation with the blood in the capillaries, and an interchange of gases readily takes place.

6. The **Pulmonary Arteries** accompany the bronchi and finally break up into the fine capillaries surrounding the air-sacs from which the veins arise.

The **Bronchial Arteries,** two or three in number, arise from the aorta, and are distributed to the bronchi, lymphatic glands, connective tissue, and mucous membrane. The right bronchial vein enters the vena azygos, and the left the superior intercostal vein.

MECHANISM OF RESPIRATION.—The lungs are compound elastic bags, communicating with the outside air, and suspended in a semi-distended state in an air-tight cavity with moveable walls. When the cavity of the thorax is enlarged by the contraction of certain muscles, the lungs become distended by drawing in air. When the muscles

relax, the lungs tend to collapse, expelling most of their contained air—a result due in part to the contraction of the elastic tissue they contain, and also to the recoil of the elastic rib cartilages.

Inspiration.—The chest enlarges in three directions, *viz.* downwards, forwards, and laterally. The enlargement *downwards* is effected by the contraction of the diaphragm. At rest the diaphragm presents a convex surface to the thorax; in contracting this surface becomes flatter, the floor of the chest is lowered, the cavity of the thorax enlarged, and air enters to distend the lungs. The contraction of the diaphragm tends to press the abdominal viscera downwards and causes the walls of the abdomen to project during inspiration.

The *antero-lateral* enlargement is effected by raising the ribs. A vertebro-sternal rib has two moveable joints, the posterior where the head articulates with the sides of the bodies of the vertebræ, and the anterior at the junction of the costal cartilage with the sternum. The anterior end occupies a lower position than the posterior, so that the rib is in more or less of an oblique position. When the anterior ends are raised, the sternum will be pushed forward, and the anterio-posterior diameter of the chest enlarged. When the ribs are raised by the external intercostal muscles, the angles which they make with the sternum become more obtuse, and the chest enlarged in the transverse diameter.

Muscles of Inspiration—Normal.—The ribs are raised by the contraction of certain muscles in normal inspiration, namely *external intercostals*, that portion of the *internal intercostals* between the cartilages, *levatores costarum* and *scaleni.* The *diaphragm* is also constantly in action during ordinary inspiration.

Laboured Inspiration.—When breathing becomes difficult other muscles come into play.

The *scaleni* are strongly contracted, so as to fix the first rib. The *serratus posticus superior* helps to raise the upper 4 or 5 ribs. The *serratus posticus inferior* and *quadratus lumborum* help to fix the lower four ribs, and thus increase the power of the diaphragm. When still further efforts are necessary, the arms and shoulders are fixed, the *serratus magnus* (scapula to upper 8 or 9 ribs), *pectoralis major* (humerus to 2nd to 6th costal cartilages), *pectoralis minor* (coracoid process to 3rd, 4th, and 5th ribs), *latissimus dorsi* (in part, *i.e.* humerus to lower ribs), help to elevate the ribs and enlarge the chest.

Expiration—Normal.—Ordinary easy expiration is effected by the elastic recoil of the lungs and costal cartilages. During inspiration the elastic tissue of the lungs is put on the stretch, and the costal cartilages and ribs are abnormally bent; both tend to return to their unstretched condition, and in doing so force out the inspired air. In this act they are aided by the *internal intercostals.*

Forced Expiration.—The *abdominal muscles*, by compressing the abdominal contents, force the diaphragm upwards and depress the sternum and lower ribs. The *quadratus lumborum*, *serratus posticus inferior*, and *sacro-lumbalis* will depress the ribs, and assist in expiration if the diaphragm is not contracting.

Summary.—Respiration is carried on under ordinary circumstances by the diaphragm and external intercostals enlarging the chest and sucking air into the lungs, followed almost immediately by the recoil of the elastic lungs and ribs forcing out the air so inspired. But when there is a more than ordinary venous condition of blood in the system, greater afforts must be made to supply the lungs with oxygen, and muscles not ordinarily employed in the effort must be brought into play. The arms and scapulæ are fixed by seizing hold of some object, and by bringing into action the trapezius, levator anguli scapulæ and rhombei, so as to make firm attachments for serratus magnus, pectorales and latissimus in their efforts to raise the ribs. Laboured expiration in like manner brings extra muscles into play. In laboured respiration the nostrils are expanded by the dilator nares during inspiration, and resume their original size during expiration. The glottis is widely open during inspiration, while it is narrowed during expiration. These movements of the glottis occur

during ordinary breathing, but are exaggerated during difficult breathing.

Rhythm and Number of Respirations.—Each respiratory act consists of three periods—(1) inspiration, (2) expiration, (3) pause. Inspiration is usually shorter than expiration, the open glottis readily admitting the air. Expiration is more prolonged, the glottis being smaller, the vocal chords being approximated, and leaving only a narrow chink. The number of respirations amounts to about 15 per minute, or 1 to every 4·5 beats of the pulse.

Vital Capacity.—The vital capacity of the chest is the amount of air which can be expired from the chest after taking the deepest possible inspiration, and is equal to about 225 to 230 cu. in.

The **Tidal Air** is the air which is constantly passing in and out of the chest during calm breathing, and amounts to 25 to 30 cu. in.

The **Complemental Air** is the air which can be drawn into the chest after taking an ordinary inspiration; it amounts to about 100 cu. in.

The **Reserve Air** is the air which can be expelled at a forcible expiration over and above the tidal air; it equals about 100 cu. in.

The **Residual Air** is the air which still remains after every effort has been made to empty the lungs; it is equal to about 100 cu. in.

Total vital capacity	Complemental	= 100	cu. in.
	Tidal	= 25—35	"
	Reserve	= 100	"
	Residual	= 100	"

The lungs normally are never quite empty, even after the most forcible expiration, but still contain about 100 cu. in. This may in part be expelled in some diseases, as in whooping cough, the lung in places being collapsed. In other diseases, as in emphysema, the lungs contain a greater amount of residual air than normally, the chest becoming more or less barrel-shaped.

Changes of the Air in Respiration.

1. Temperature. The expired is warmer than the inspired air; the temperature depending to some extent upon the temperature of the inspired air, and the rate and depth of the breathing.

2. The expired air is saturated with aqueous vapour.

3. The expired air contains 4 to 5 per cent. less oxygen, and about 4 per cent. more carbonic acid gas.

	O	N	CO_2
Inspired air . .	21	79	·04
Expired air . .	16	79·5	4·3

A certain amount of oxygen does not reappear in the expired air, in the form of carbonic acid.

During 24 hours an adult man gives out about 800 grammes (12,300 grains) of CO_2, containing 218 grammes (3,300 grains) of C, and consumes about 700 grammes (11,000 grains) of O.

4. In addition to carbonic acid, the expired air contains ammonia, and other unknown substances of a poisonous or deleterious nature. An atmosphere containing ·08 per cent. of CO_2, with the accompanying impurities, is unwholesome, while ·1 per cent. of CO_2, with proportional amount of impurities, is very injurious.

Changes in the Blood.

1. It is cooled.
2. It loses watery vapour.
3. It gains oxygen (8 to 12 per cent. per vol.) The amount of oxygen in the blood rising from about 12 to 20 per cent. per vol.
4. It loses carbonic acid (7 per cent. per vol.) The amount of CO_2 in the blood falling from 46 to 39 per cent (*see* p. 56).

Circumstances affecting the Excretion of Carbonic Acid.

1. Muscular Exercise.
2. Food.
3. Age.
4. Disease.

1. Muscular exercise increases the amount of carbonic acid exhaled. E. Smith found that there was expired—

	Per minute
During sleep . .	4·99 grains.
Lying down . .	5·91 „
Walking 2 miles an hour	18·10 „
Walking 3 miles an hour	25·83 „
Exercise on treadmill .	44·97 „

2. The amount exhaled in the expired air is increased by food, especially starchy foods.

3. The amount exhaled increases up to the 30th year, and diminishes after 45.

4. Many diseases, as the fevers, increase the amount of CO_2 in the expired air.

ABNORMAL RESPIRATION.—If the blood in the body contains more than an ordinary amount of oxygen, no efforts to breathe will take place; this condition is called **Apnœa.** The ordinary natural condition of respiration is termed **Eupnœa.** As soon as the blood in the body becomes more venous than ordinarily, in consequence of the amount of oxygen sinking below normal, the respiratory movements become quicker, and both inspiratory and expiratory efforts are increased by bringing extra muscles into play. This condition of difficult breathing is termed **Dyspnœa.** As the blood becomes more and more deficient in oxygen, the respiratory efforts become more laboured, the expiratory

movements becoming more marked than the inspiratory. The expiratory efforts become convulsive in character, and the whole muscles of the body presently take part in the convulsions. In the last stage the convulsions cease, coma sets in, the pupils dilate, the conjunctivæ are insensible, while at intervals respiratory efforts, chiefly inspiratory, are made. The term **asphyxia** is applied to the later stages following dyspnœa, when insensibility has set in. Thus in oxygen starvation three stages may be witnessed. (1) A stage of dyspnœa, characterised by increased respiratory movements, both inspiratory and expiratory. (2) A convulsive stage, in which expiratory efforts are most marked. (3) A stage of coma, marked by insensibility, and slow, deep inspiratory efforts.

When the trachea of a dog is suddenly occluded, the first stage lasts about one minute; the second stage also lasts a minute; in the third stage some two or three minutes elapse before death ends the scene.

The Circulation in Asphyxia.—During the inspiratory and expiratory efforts of the first and second stages the blood pressure rises, but during the third stage it sinks till death ensues. The rise of blood pressure is brought about by constriction of the smaller arteries, the result of their carrying venous blood; the left side of the heart becomes full; the increased respiratory movements assist the return of blood to the right side of the heart, so that

the cavities on both sides of the heart become distended. The distended heart at first beats more quickly, then more slowly and forcibly, and finally becoming exhausted from being continually supplied with venous blood, ceases all together. The heart continues to beat for some time after the respiratory movements have ceased. At a post-mortem examination, it will be found there is a distended right side, but an empty left, rigor mortis having caused contraction of the left ventricle.

Asphyxia due to Oxygen Starvation.—When an animal is made to inhale nitrogen only, the exit of carbonic acid is not interfered with, yet all the effects of dyspnœa and asphyxia ensue, a result due to the absence of oxygen in the blood. If an animal breathe an atmosphere rich in carbonic acid and with plenty of oxygen, the breathing becomes deeper at first; this afterwards passes off, and the animal becomes unconscious, without any convulsive movements, the carbonic acid acting as a narcotic poison.

The Nervous Mechanism of Respiration.—Breathing is a reflex act, capable of being modified by the will. The nerve centre is situated in the medulla, the *afferent* nerves are the vagi, the efferent nerves are the phrenics, intercostals, &c. Respiration continues in the absence of consciousness and after the removal of the brain above the medulla; but destruction of a certain small portion of the

medulla below the vaso-motor centre causes the movements at once to cease. This spot is called the *nœud vital.* This centre is influenced by impulses from without or within—a dash of cold water in the face, a cold bath, an emotion, venous blood in the pulmonary vessels, all call it into action. The centre is probably automatic as well as reflex, section of the vagi thereby interrupting the channel by which the afferent impulses reach it from the lungs, while interfering with the respiratory act does not stop it. Automatic impulses descend from the centre along the efferent nerves. Probably the venous blood circulating through the centre itself supplies the stimulus.

Section of Vagi.—If one vagus is divided respiration is slower, if both are divided it becomes very slow, while each respiration is fuller and deeper, so that the amount of carbonic acid given off is not much altered. During life the terminal fibres of the vagi are stimulated by the venous blood in the pulmonary capillaries, the stimulus travelling upwards to the medulla. The more venous the blood, the more intense the stimulus transmitted upwards, and the greater the number of muscles brought into play. If the central end of a divided vagus be stimulated by the interrupted current, the respirations are quickened; if the stimulus is increased, the diaphragm is brought into a tetanic condition. Stimulation of the central end of the

superior laryngeal causes a slowing of the respiratory movements to take place, the diaphragm becoming relaxed if the stimulus is sufficiently intense.

Coughing consists in a deep inspiration, followed by a closure of the glottis, and finally a sudden forcible expiration, which bursts open the glottis and forces out any mucus or foreign matter present in the air passages. The *afferent* impulses travel along the superior laryngeal nerve from the larynx, or the vagi from the bronchi, lungs or pleura, or the auricular branch distributed to the outer ear.

Sneezing closely resembles coughing, except that the expiratory blast is driven through the nose, the soft palate and anterior pillars of the fauces shutting off the mouth from the pharynx; the afferent impulses travelling along the fifth.

Hiccup is caused by the spasmodic action of the diaphragm, causing a sudden inspiration and closure of the glottis. The afferent impulses travel along the vagi from the stomach.

Effects of Respiration on the Circulation.—If a tracing be taken by means of a kymograph connected with the carotid of a dog, it will be seen that, in addition to the small oscillations produced by the intermittent action of the heart, there are larger waves which correspond with the respiratory movements. The summit and base of the waves do not exactly correspond with either inspiration or expiration. At the beginning of inspiration arterial

pressure, as shown by a tracing, is falling; it soon begins to rise, and reaches its maximum soon after the commencement of expiration.

If a dilated vein, often seen in the neck, is watched, or the vein of a dog be laid bare, it will be noticed that during inspiration the vein collapses, and during expiration it is distended. It appears therefore that inspiration lowers the tension in the venous system, and increases tension in the arterial, though the latter effect does not reach its maximum till expiration has begun. These effects are produced in the following manner: The expansion of the cavity of the chest during inspiration not only draws air down the trachea, but tends also to suck the blood in the veins and arteries immediately outside the chest to the heart. Thus death may be caused by an injury to the veins of neck, air being drawn in. The arterial system, with its high pressure, is but little affected; not so the blood in the large veins; during an inspiration, blood in the innominates and inf. v. cava will rush towards the right side of the heart; more will pass through the pulmonary vessels, the left ventricle becomes more distended, and its beats more forcible, increasing tension in the arterial system, though, as before remarked, the maximum does not occur till after the commencement of the following expiration. In expiration the negative pressure in the veins caused by inspiration is removed, the flow of blood

in the veins is no longer assisted, less blood enters right side of heart, and consequently less blood enters left side, and arterial pressure falls. Expiration, however, tends to increase arterial tension by direct pressure on the thoracic aorta, but to so small an extent that its effects may be disregarded.

SECTION VII.

ANIMAL HEAT.

HEAT is generated throughout the body wherever oxidation processes are going on. Whenever arterial blood comes in contact with active protoplasm, in the glands, muscles, or tissues, heat is produced. The hæmoglobin gives up its oxygen to the carbon and hydrogen present in the blood or tissues, forming CO_2 and H_2O, and generating heat.

Cold-blooded Animals are those whose oxidation processes are feeble, so that their temperature is but slightly raised above, and varies with that of the medium in which they live. All classes of animals are cold-blooded except birds and mammals. The temperature of the frog is only slightly above that of the air, though it is 1° or 2° C. higher during the breeding season. Some fishes and snakes have a temperature of 10° C. above the medium in which they live. In the cold-blooded animals, the amount of heat generated within their tissues is slight, and their temperature will vary with the season and the circumstances under which they are placed.

Warm-blooded Animals are those in which the oxidation processes are vigorous, so that they maintain a temperature considerably above that of the surrounding medium, and it is so regulated that it remains constant notwithstanding a variation of temperature in surrounding objects. In man, the average temperature is 37° C. (98·6° F.) (axilla); in some birds, as the swallow, it is 44° C. (111° F.), the more active birds having a higher temperature than mammals. This temperature remains nearly constant, notwithstanding the changes of temperature in different seasons and climates. Slight elevations of temperature take place when the external air is considerably raised, as in a Turkish bath (100·6° F. in a bath of 120° F). In disease there is often a notable rise of temperature; in scarlatina or typhus it may rise to 41·2° C. (106° F.), in acute rheumatism 43·3° C. (110° F.), and in one case of fracture of the spine to 50° C. (122° F.) In other diseases, as in uræmia and cholera, it sinks below normal.

The temperature of 98·6° is the resultant of two sets of processes.

I. Those by which heat is gained.
II. Those by which it is lost.

I. Heat is gained to the Body—

1. Wherever arterial blood comes in contact

with active protoplasm, chemical changes taking place.

2. By friction of the muscles.

3. By ingestion of hot liquids and foods.

II. **Heat is lost to the Body—**

1. By means of the skin—evaporation of the perspiration, radiation, and conduction, 77·5 per cent.

2. By the lungs—evaporation of the water of respiration, and warming expired air, 20 per cent.

3. By escape of urine and fæces, 2·5 per cent.

The warmest blood in the body is that of the hepatic vein. The liver is the largest gland in the body, and its cells are constantly engaged in effecting chemical changes in the blood circulating through that organ. Blood returning from active muscles is warmer than the blood supplied to them. The brain, spleen, and pancreas, when in an active state, are a source of heat to the blood.

The circulation of the blood ensures an equable temperature throughout the body by distributing the heat. But in order to maintain an average temperature of 98·6° under different circumstances, as regards external heat, the amount of blood supplied to different parts must be regulated. The amount of heat lost by the skin will depend upon the amount of blood circulating through the vessels near the surface of the body. If the cutaneous

arteries are dilated, an increased amount of heat will be lost by evaporation of the perspiration poured out, as well as by radiation and conduction, and less blood is supplied to the internal organs where heat is produced. Thus, if the body be exposed to cold, the vessels of the skin are contracted and less perspiration poured out, and more blood is supplied to the liver and internal organs, and more heat generated as well as less lost. But if the body be exposed to heat, as in a Turkish bath, the cutaneous vessels are dilated, perspiration is poured out and evaporated, more heat is lost and less generated in the internal organs.

The exact conditions under which the increased amount of heat is produced in fevers or acute rheumatism is unknown.

One of the functions of the vaso-motor system is to regulate the size of the arteries and therefore the amount of blood supplied to a part. Increased supply of blood to a part will increase the tissue change and thereby the temperature, or if it be near the surface, its temperature will be increased from a greater supply of blood, warmer than itself. Section of the sympathetic in the neck is followed by redness and heat of the corresponding ear and side of the face, a difference of 4° to 6° C. being noticed.

Injuries to the central nervous system, as in effusion of blood in the brain or some injury to spinal cord, is often followed at first by a lowering,

probably from shock, and then in a few hours an increased temperature ranging up to 108° F. or more. In hemiplegia, the temperature of the paralysed side is generally one or two degrees higher than the sound side, but in old cases of paralysis the paralysed limbs are often cooler, apparently from defective circulation. The vaso-motor centre being situated in the medulla, any interference with its action will be likely to alter the temperature of the body by interference with the blood supply.

SECTION VIII.

FOOD.

Foods may be divided into—

1. Nitrogenous.
2. Hydro-carbons, or fats.
3. Carbo-hydrates, or starches.
4. Inorganic.

Nitrogenous.—N enters largely into the compo sition of the tissues; it requires, therefore, to enter the body in the form of food, to replace the loss which is continually taking place. The nitrogenous principles present in the food are—

Albumin	Syntonin	Vegetable albumen.	
Fibrin	Globulin	do.	fibrin (gluten).
Casein	Gelatin	do.	casein (legumine).
Vitelline	Chondrin.		

The nitrogenous principles undergo digestion in the stomach and intestines, and are converted into the peptones. The peptones are absorbed by the portal vein, and pass through the liver before entering the general circulation. The changes they undergo in the liver are not well understood.

Destiny of Nitrogenous Foods.—1. Development and renovation of the tissues; 2. To assist in the formation of the secretions; 3. Force production.

1. During infancy, the rapid cell-growth requires abundant nutriment in the form of albuminous matters. Throughout the whole life there is a continual wear and tear of the tissues; each individual cell has a period of activity and a subsequent death; albuminous material is required to replace the cells which have perished. Thus, the epithelial cells on the surface of the skin are constantly being worn away, and require renewal from the deeper cells. The red corpuscles, the secreting epithelium of the various glands, after remaining in an active state for a certain period, perish, and fresh ones are needed to replace them.

2. The secretions of the body, as the gastric and pancreatic juices, are constantly using up albuminous material to form their active principles.

3. *Force-production.*—Liebig maintained that nitrogenous food was utilised to build up the proteid tissues, as muscle and other forms of protoplasm, and that urea, uric acid and their allies, arose solely from the breaking up of these tissues, while non-nitrogenous food was used exclusively for the maintenance of heat or was stored as fat. The mechanical energy of the body being derived from the oxidation

of the muscles, or formed nitrogenous material. If this were true, the amount of muscular exercise would be proportional to the amount of urea appearing in the urine. This has been frequently disproved. It has been shown by Parkes, Fick, Wislicenus and others, that the urea is very slightly increased by muscular exercise, not in proportion to the work done. While the amount of urea in the urine has been shown to be proportional to the amount of albuminous food ingested. Probably some portion of the albuminous food taken is split up, the N escapes from the system as urea, CON_2H_4, leaving roughly about $\frac{2}{3}$ of its original weight, consisting of CHO, to be stored as fat or glycogen, or oxidised in the system, supplying mechanical energy or heat, and escaping as CO_2 and H_2O. Thus :—

Albumen	$= C = 53{\cdot}5$	Urea	$= C = 20$
	$= H = 7$		$= H = 6{\cdot}6$
	$= N = 15{\cdot}5$		$= N = 46{\cdot}6$
	$= O = 22$		$= O = 26{\cdot}6$
	$= S = 1{\cdot}6$		
	$= P = {\cdot}4$		
	100		100

Nitrogenous foods have not all the same dietetic value. The albuminoids, gelatin, and chondrin are inferior to albumen. Their ingestion is followed

by an increased quantity of urea in the urine. But gelatin alone, or in combination with fats or starches, will not maintain life. Probably no part of the gelatin compounds are utilised in the nutrition of the tissues, but are split up into urea and some fatty body.

Dynamic Value of Nitrogenous Foods.—Albumen, when completely oxidised, is converted into NH_3, CO_2, and H_2O. It is not completely oxidised in the body, being converted into urea, uric acid, CO_2, &c., some (about one-seventh) therefore of its energy is unexpended.

One gramme of beef muscle, when completely oxidised, will give out sufficient heat to raise	5,103 grammes of water 1° C., or 2,161 kilogrammes, 1 metre
One gramme of beef muscle, as oxidised in the body	4,368 gramme-degrees, or 1,850 kilogramme-metres.

Hydro-carbons, or Fats, are neutral bodies derived from both animal and vegetable foods. They consist of *olein*, *palmitin*, and *stearin*. Olein and palmitin are met with both in animal and vegetable products; olein is fluid at ordinary temperatures; palmitin has a semi-fluid consistence. Stearin is a solid fat, is found only in animal products, and exists largely in suet. They all have glycerine for a base in combination with the cor-

responding fatty acids, oleic, palmitic, and stearic. The fats are remarkable for the small quantity of O they contain; thus in palmitic acid, C_{16}, H_{32}, O_2, the amount of O is about 12 per cent. of its weight, leaving from 80 to 90 per cent. available for force production.

Digestion of Fats.—The gastric juice dissolves the connective tissue binding together the fat vesicles and sets free the fat. The fatty matters are emulsified in the small intestine by the action of the pancreatic juice, and in a lesser degree by the other secretions, and for the most part enter the lacteals, though a certain proportion, which has possibly become saponified, enters the portal vein.

Destiny of Fats.—The fats are utilised in the body for force-production, either immediately or are stored as adipose tissue to be used when required. They therefore serve for the maintenance of heat and performance of muscular work. The capacity of a material for force-production depends upon the amount of unoxidised C and H it contains, and of all alimentary substances fats take the highest place. Experimentally, Frankland has shown, that the actual heat developed by the various alimentary substances when burnt in O is as follows:—

1 gramme	beef fat	9,069	gramme-degrees.	
„	butter	7,264	„	„
„	beef muscle	5,103	„	„
„	arrowroot	3,912	„	„

That is to say, 1 gramme, or 1 lb. of fat when burnt, will give off heat sufficient to raise 9,069 grammes, or 9,069 lbs. (about 4 tons) of water, 1° C. Whereas the same amount of arrowroot would, when burnt, only raise 3,277 grammes of water 1° C.

It is found that the inhabitants of arctic regions readily devour all kinds of fat, while in the tropics the foods of the inhabitants consist largely of farinaceous and saccharine matters. The force generated by the oxidation of the hydro-carbons is available for muscular work. A large amount of muscular work can be performed on a fatty or starchy diet. During muscular exercise, the amount of CO_2 given off at the lungs varies according to the work done; thus, 5 grs. per minute during sleep, and 25 grains per minute walking at the rate of three miles an hour.

The amount of mechanical work obtainable from the oxidation of—

1 gramme beef fat	= 3,841	kilogramme-metres	
,, butter	= 3,077	,,	,,
,, beef muscle	= 2,161	,,	,,
,, arrowroot	= 1,657	,,	,,

That is, the force derivable from the oxidation of 1 gramme of fat, is sufficient to raise 3,841 kilo-

grammes one metre. (1 kilogramme-metre=7·232 foot-pounds.)

The products of the combustion of fat are H_2O and CO_2. Animal life cannot long be maintained on a non-nitrogenous diet. Dogs fed on fat, or fat and starches, emaciate and die. Nitrogenous food is required to renew the tissues, which become wasted and worn during the processes of life.

Carbo-hydrates or Amyloids comprise starch, cane sugar, grape sugar, milk sugar, glycogen. Chemically these bodies differ from the fats in containing a smaller quantity of uncombined carbon and hydrogen. The O existing in sufficient quantity to form water with all the H present, starch ($C_6H_{10}O_5$), grape sugar ($C_6H_{12}O_6$).

Starch is met with in the vegetable products. It is prepared for absorption by being converted into grape sugar in the mouth and small intestine. Cane sugar and glycogen are converted into grape sugar in the stomach and intestines. Milk sugar ($C_{12}H_{22}O_{11}+H_2O$) and grape sugar ($C_6H_{12}O_6+H_2O$) are readily absorbed by the portal vein and submitted to the action of the liver. Here some change takes place. Sugar injected into the jugular vein rapidly appears in the urine; injected into the portal it does not, unless in large quantity. The grape sugar is converted in the liver into

glycogen ($C_6H_{12}O_6 - H_2O = C_2H_{10}O_5$) and probably also into fat.

It is uncertain whether the glycogen is reconverted into sugar and oxidised in the system, or whether it enters the system as glycogen or some similar body. In any case it is oxidised, being converted into CO_2 and H_2O, and giving rise to heat, and supplying force for the performance of work.

INORGANIC MATERIALS.

Various salts exist in the body in combination with the organic materials that form the tissues. The chief salts consist of calcium, sodium, potassium, magnesium, and iron, in combination with chlorine, phosphoric, carbonic, and sulphuric acids.

DIETETICS.

Experience proves that a mixed diet is the best to maintain the body in health. Dogs will not live on hydrocarbons or carbo-hydrates alone. Too much nitrogenous food leads to an excessive amount of urea and uric acid, and throws increased work on the excretory organs.

Milk, the food of early life, may be taken as a typical illustration of a natural combination of the various foods.

Milk contains—

	Cow	Woman
Nitrogenous matters (casein and albumen)	4·1	3·35
Butter	3·9	3·34
Milk sugar	5·2	3·77
Salts	·8	
Water	86	89·54
	100	

Cow = 14 per cent. solids.
Woman = 11 per cent.

Normal Diet.—The normal diet for a man in health can only be arrived at by experience. Taking the average of a large number of healthy persons, it has been found that the following diet will suffice :—

Dry food.	ozs.
Albuminous matter . .	4·5
Fatty matter	3·
Carbo-hydrates . . .	14·2
Salts	1·0

Thus about 23 ozs. of dry solid food are contained in this standard diet, about $\frac{1}{5}$ of which is nitrogenous. If we reckon that 50 per cent. of ordinary food is water, these 23 oz. will correspond to 46 oz. of ordinary solid food. In addition about 50–80 ozs. of water are taken. The force-producing value of this standard diet is nearly 4,000 foot-tons.

The standard diet will necessarily be altered under different conditions.

It is said that an Esquimaux eats about 20 lbs.

of flesh and oil daily, and men working heavily necessarily require more than when at rest.

Hard Work Diet.—The average dietary of a labourer performing hard work has been calculated at—

Nitrogenous matter . .	5·08 ozs.
Fat	3·9 „
Carbo hydrates . .	22·2 „
Mineral	·9 „

Dynamic value 5,232 foot-tons.

Taking the model diet for ordinary men—

	ozs.	N.	C.
Nitrogenous matter	4·5	316	1068
Fat . . .	3·0		1024
Carbo-hydrates .	14·25		2768
		316 grs.	4860 grs.

It appears, therefore, that a man on ordinary diet and doing an ordinary amount of work requires 300 grs. of N and 4,800 grs. of C.

The ratio of the quantities is 1–16. In albumen the ratio is 1–3·5. Hence, if albumen alone were used, and the 300 grains of N were supplied, there would be a deficiency of C, and if the 4,800 grains of C were supplied, there would be more N than required. In bread the ratio is as 1–30; so that if bread alone were used, there would be a superfluity or deficiency of either N or C. Two

pounds of bread and three-quarters of a pound of meat will fulfil the above conditions, though it will better do so if 1–2 ozs. of butter be added.

Effects of Starvation.—The most prominent symptoms are first pain in the epigastrum, relieved by pressure; this subsides in a day or two, and is succeeded by a feeling of weakness and of intense thirst. The countenance becomes pale, the body exhales a peculiar fœtor, and the bodily strength rapidly fails. The temperature is lower than normal. The mental powers exhibit similar weakness, first stupidity, then imbecility, which sometimes is succeeded by maniacal delirium. Life terminates by gradually increasing torpidity, or, occasionally, by a convulsive paroxysm.

With entire abstinence from food and drink, death occurs in from eight to ten days. The Welsh fasting girl lived eight days. This time may be prolonged if water can be obtained, or if surrounded by a warm, damp medium.

The loss during starvation falls most heavily on the fat, next the glandular organs, then the muscles, the heart and brain being affected least. The post-mortem examination shows extreme emaciation and complete absence of fat. All the organs, with perhaps the exception of the brain, are bloodless; the coats of the intestines thin and empty of contents. The gall-bladder full, the bile staining the surrounding parts. The body rapidly passes into decomposition.

SECTION IX.

DIGESTION.

TEETH.

Two sets of teeth make their appearance during the life of man.

I. *The temporary, or milk teeth* (20).

II. *The permanent set* (32).

I. **The Temporary Set** appear during the first two years of life. They consist of two incisors, one canine, and two molars, in each half-jaw, making twenty in all. They appear in the following order, the numbers referring to the months :—

Incisors, 7, 9. Canines, 18. Molars, 12, 24.

There are no bicuspids in the temporary set. They resemble the permanent teeth in general form, but are considerably smaller.

II. **The Permanent Set.**—The first six months of life are passed without any teeth ; by the end of the second year the milk teeth have all appeared, and these begin to be replaced by the permanent set at the sixth year, and are completely replaced

by them at the twelfth or thirteenth year; the teeth being completed by the eruption of the wisdom teeth at the age of about twenty-one. When complete there are thirty-two, there being two incisors, one canine, two bicuspids, and three molars, in the half of either jaw. They replace tho temporary set in the following order, the numbers referring to the years of age :—

Incisors, 7, 8. Canine, 11. Bicuspids, 9, 10. Molars, 6, 12, 21.

The **Incisors** (8) are arranged side by side in the front of the jaws. They have a single long conical fang, and a sharp chisel-shaped edge, for dividing the food.

The **Canines** (4) are placed singly, next to the lateral incisors. Their fangs are single, large, and conical, compressed laterally, and cause a prominent ridge in the alveolus of the jaw. The crown is more pointed than in the incisors.

The **Bicuspids** (8) are arranged four in each jaw. The fangs are bifid at their apices, more marked in the upper and second bicuspids, and are grooved laterally. The crown is compressed from before backwards, and is surmounted by two tubercles, or cusps, separated by a groove.

The **Molars** (12) are arranged three in each jaw, behind the bicuspids. They have from two to three fangs. In the two anterior molars of the upper jaw they are three in number, two ex-

ternal and one internal. The two anterior molars of the lower jaw have two fangs, one anterior and one posterior. In the third molar, or wisdom tooth, the fang is irregular and single. The crowns of the molar teeth are cuboidal in form, rounded on each lateral surface, and flattened in front and behind. The upper molars have four cusps at the angles of the grinding surface, separated by a crucial depression: the lower molars have five cusps. The molars, from the great breadth of their crowns, are suitable for grinding and pounding the food.

Structure.—*Minute anatomy*—

A tooth consists of a *crown*, which projects from the gum, a *root* or *fangs*, which are fixed in a socket in the bone, and a short intermediate *neck*. Each is supplied with an artery and nerve, and has a central cavity filled with a soft vascular sensitive substance, the pulp.

1. Pulp.	3. Dentine.
2. Crusta petrosa.	4. Enamel.

1. The *pulp* occupies the central cavity of the tooth, and consists of fine connective tissue, nucleated cells, blood-vessels, and nerves. The cells, or odonto-blasts, are said to send fine processes into the dentine tubules. The arteries are derived from the internal maxillary and nerves from the fifth pair.

2. The *crusta petrosa,* or cement, covers the fang of the tooth, its place being taken below by the enamel which covers the crown. In structure it resembles bone, containing lacunæ and canaliculi, but they are larger and more irregular.

3. The *dentine* forms the principal mass of the teeth, being protected by the crusta petrosa and enamel, and hollowed out in the centre to form the pulp cavity. It is somewhat harder than bone, and differs from it in structure. It is penetrated by numerous fine tubes, giving it a striated appearance beneath the microscope, the tubes appearing dark and the matrix transparent. The tubules open into the pulp cavity, and radiate to the periphery, giving off small branches. They are $\frac{1}{4500}$ in. in breadth, and have a distinct wall, the dental sheath. As the dentine is sensitive, it is possible they may convey nerve fibres as well as prolongations of the cells of the pulp cavity. The matrix is homogeneous.

4. The *enamel* is very hard and covers the crown. It is made up of microscopic prisms arranged side by side; these prisms are six-sided and $\frac{1}{5000}$ in. in diam., and are marked at intervals by transverse lines.

Chemical Composition.—The hard tissues of the teeth, like bone, consist of animal matter and mineral matter : the former yields gelatin on boiling, and exists in different amounts in the tissues—

Bone . .	33	per cent.	animal	matter.
Crusta petrosa	30	"	"	"
Dentine . .	28	"	"	"
Enamel . .	3·5	"	"	"

The mineral matter consists of calcic phosphate and carbonate, magnesic phosphate and calcic fluoride.

Development.—At the seventh week of intra-uterine life, a groove appears on the surface of the jaws, which involves the soft embryonic tissues of the jaw as well as the Malpighian layer of the epithelium. It was called by Goodsir the *primitive dental groove.* This down-growth of epithelium forms the *common enamel germ,* and from it the enamel is developed. From the bottom of this groove, which has become flask-shaped in section, papillæ, twenty in number, arise. These papillæ become enclosed in sacs, and form the future tooth by becoming vascular, and lime salts being deposited.

The ten anterior permanent teeth in each jaw are formed from small grooves behind the milk teeth, which are converted into cavities, and are termed '*cavities of reserve.*' A little papilla forms in each cavity, and forms the future permanent tooth. The six posterior teeth, or molars, arise from extension of the primitive groove backwards, and have been named '*posterior cavities of reserve.*'

THE TONGUE.

The tongue is a muscular organ which plays an important part in articulation, mastication, and deglutition; it is covered with mucous membrane, containing the organ of taste.

The mucous membrane surrounds the tongue, and forms various folds, as it is reflected to neighbouring parts. In the middle line, on the under surface, is the frænum linguæ, and on the upper surface, behind, are the three glosso epiglottidean folds. In structure it resembles the skin, having a cutis, with papillæ covered by a stratified flattened epithelium. The under surface of the tongue is smooth, the upper surface, especially the anterior two-thirds, is rough, from the presence of numerous special *papillæ*. There are three kinds of papillæ, circumvallate, fungiform, filiform.

The **Circumvallate** papillæ are eight to ten in number, situated at the back of the tongue, arranged in the form of the letter V with the apex backwards. They are rounded in form, and $\frac{1}{12}$ in. in width; their attached ends being somewhat narrower than their free ends, and are situated in a cup-shaped depression, which surrounds them like a trench. They are beset with numerous secondary papillæ, which are covered by the flattened stratified epithelium that lines the tongue. Embedded in the sides of the papillæ are numerous

flask-shaped bodies composed of modified epithelium cells called *taste-buds,* with which the nerve-endings are connected. The papillæ are supplied with an arterial twig and nerve.

The **Fungiform** papillæ are smaller than the preceding, and are scattered over the dorsum, more particularly at the sides and apex. They are of a deep red colour, narrow at their attached ends and broad and rounded at their free extremities. They contain some of the taste-buds, and are supplied with nerves and capillaries.

The **Filiform** papillæ cover the anterior two-thirds of the dorsum of the tongue: they are long and slender, and of a whitish tint. They are covered by a peculiar kind of epithelium, which is dense and imbricated, and possesses many hair-like processes.

Glands.—There are numerous small racemose glands, resembling minute salivary glands in structure, beneath the mucous membrane; some of them open into the fossa surrounding the circumvallate papillæ, and secrete a thin saliva and mucus.

The **Tonsils** are two rounded bodies situated between the anterior and posterior pillars of the pharynx. In structure they consist of lymphoid tissue; some twelve or fifteen recesses, or crypts, open on the anterior surface.

MASTICATION.

The first stage in the digestion of food consists in its mastication in the mouth. It is crushed between the teeth and rolled about by the movements of the tongue to mix it thoroughly with the saliva.

The movements of the muscles are voluntary, though from use they become habitual in character, and will continue when the influence of the will is withdrawn and the attention directed elsewhere, provided there is a sensation of hunger and food within reach. The mouth is opened by the anterior belly of the digastric, mylo-hyoid and genio-hyoid muscles. It is shut by the combined action of the masseter, temporal, internal pterygoid muscles. The external pterygoids acting together thrust the jaw forward: it is retracted by the posterior fibres of the temporal. The grinding movement is performed by the alternate actions of the external pterygoids. The tongue on the inner, and the buccinator on the other side, press the food between the molars, and the action of the zygomatici helps to keep the buccinator and mucous membrane of the cheek from being included between the teeth.

SALIVA.

The *Saliva* is secreted by three glands, parotid, sub-maxillary, sub-lingual, and also by the smaller glands beneath the mucous membrane of the tongue and cheeks.

Structure of Salivary Glands.—They are compound racemose glands, and consist of numerous lobules, each supplied with a duct and blood-vessels, and bound together by connective tissue. The duct divides and redivides in the lobule until its smaller divisions enter a cluster of saccules, or acini. These acini are lined by spheroidal epithelium with well-marked nuclei; the cells occupy nearly the whole of the acinus, leaving a very small lumen in the centre. The ducts are lined by columnar epithelium.

Composition.—Saliva is a viscid, frothy alkaline fluid, S. G. 1002–1007, and containing about $\frac{1}{2}$ per cent. of solid matter. From 30 to 60 fluid ozs. are secreted in twenty-four hours.

It contains—

1. Mucin.
2. Ptyalin.
3. Albumen.
4. Salts.
5. Water.

Microscopically, epithelium cells, mucus and salivary corpuscles are seen.

Ptyalin is an albuminous body of the nature of a ferment.

The *salts* include potassium sulpho-cyanide; the latter salt is recognised by its giving a red colouration with ferric chloride, which is unaltered by HCl, and destroyed by mercuric chloride $HgCl_2$.

Uses.—1. Converts starch into dextrin and grape sugar. 2. Moistens the food, and therefore assists in mastication and deglutition. 3. Administers to the sense of taste by dissolving the food.

The conversion of starch into sugar consists in the addition of a molecule of water—

$$3\ C_6H_{10}O_5 + 3\ H_2O = 3\ C_6H_{12}O_6.$$

Innervation of the Salivary Glands.—The secretion of saliva is a reflex act, due to the excitation of food placed in the mouth, or to mental stimuli induced by the sight or thought of food.

The arteries supplying the gland are influenced by two opposing nerves, (1) the *vaso-motor*, which narrow their calibre and diminish the supply of arterial blood to the gland, and therefore lessen secretion; (2) the *vaso-inhibitory*, which antagonise the vaso-motor, and hence increases alike the blood supply and the secretion of the gland. The vaso-motor are derived from the sympathetic, the vaso-inhibitory for the sub-maxillary gland from the chorda tympani, passing through the sub-maxillary ganglion, and for the parotid, the lesser superficial petrosal, passing through the otic ganglion.

The presence of food in the mouth excites the

terminal fibres of the gustatory (5th) and glosso-pharyngeal nerves; the sensation is transmitted to the medulla; it is reflected along the chorda tympani, which, by inhibiting the sympathetic, dilates the blood-vessels, and increases the functional activity of the sub-maxillary gland, and saliva is poured out. According to Heidenhain, the chorda tympani contains fibres which directly stimulate the epithelium, as well as fibres which inhibit the sympathetic, the former being paralysed by atropin.

In the dog the parotid secretion is the most watery and the sublingual the most viscid. According to Bernard, the sub-maxillary administers to the sense of taste, the parotid being connected with mastication, and the sublingual with deglutition.

DEGLUTITION.

Deglutition is a complicated act by means of which food passes from the mouth into the œsophagus without any part of it being allowed to enter the nasal cavity or the larynx. It is usually divided into three acts—

1. The passage of food to the back of the mouth.
2. Its passage across the orifice of the larynx.
3. Its seizure by the constrictors and its passage through the œsophagus to the stomach.

1. The bolus having been prepared, the tongue carries it back through the anterior pillars of the

fauces, the movement being effected through the agency of the stylo-glossus and intrinsic muscles of the tongue.

2. The soft palate is raised by the action of its muscles, and assisted by the contraction of the upper part of the superior constrictor, shuts off the cavity of the nose from the pharynx. The larynx is raised behind the hyoid bone by the action of the stylo-pharyngeus and thyro-hyoid, the vocal chords are approximated and the epiglottis closely fitted over the rima glottidis by the action of the depressor. The passages both into the nares and larynx being closed, the descending bolus passes over the root of tongue, epiglottis, and beneath a roof formed by the contraction and approximation of the palato-pharyngeal muscles, is seized by the constrictors, and propelled into œsophagus.

Deglutition is a reflex act.

Afferent Nerves.—Glosso-pharyngeal and branches of 5th.

Nerve Centre.—In the medulla.

Efferent.—Pharyngeal branch of vagus, hypoglossal, glosso-pharyngeal, and facial.

THE ŒSOPHAGUS.

The Œsophagus is the muscular tube extending from the pharynx to the stomach. It consists of three coats—

1. External, or muscular.
2. Middle, or submucous.
3. Internal, or mucous.

1. The **External** consists of an outer layer of longitudinal and an inner layer of circular muscular fibres. The muscular fibres in the upper part are striated, but are gradually replaced by non-striated in the lower half.

2. The **Submucous** coat consists of connective tissue, and contains some mucous glands.

3. The **Mucous** coat is pale in colour, and when the œsophagus is contracted is thrown into longitudinal folds. In structure it resembles the skin, having a cutìs, papillæ, rete mucosum, lined by stratified flattened cells.

The food is propelled along the œsophagus by the peristaltic action of its muscular walls. It is a reflex act: the afferent and efferent nerves are supplied by the vagus. Food accumulates in the œsophagus of an animal in which the vagus is divided below the pharyngeal branches, the animal being able to swallow the food, but the œsophagus fails to pass it on into the stomach from paralysis of its muscular walls.

STOMACH.

Structure.—Four coats—

1. Serous.	3. Submucous.
2. Muscular.	4. Mucous.

1. The **Serous** is derived from the peritoneum; it invests the whole organ, except at the curvatures.

2. The **Muscular** contains fibres of the non-striated variety. *Longitudinal,* best marked along the curvatures and near the pylorus. *Circular,* forming a complete layer over the whole extent of stomach, becoming thick and strong at the pylorus and forming the sphincter. *Oblique,* scattered over surface and continuous with circular of œsophagus.

3. The **Submucous** consists of a layer of connective tissue between the muscular and mucous.

4. The **Mucous** is a smooth pink membrane, which is loosely attached to the tissue beneath, and when the stomach is empty is thrown into rugæ. The mucous membrane contains a fine layer of muscular tissue, the *muscularis mucosæ,* internal to which are the tubular glands.

Tubular Glands.—On examining a section of stomach stained with logwood or aniline, rendered transparent with glycerine, the tubular glands are seen parallel to one another and closely crowded together, with their blind extremities towards the muscularis mucosæ, and opening on the surface of

the mucous membrane. Their length varies from $\frac{1}{20}$ to $\frac{1}{60}$ in. and diam. $\frac{1}{300}$ to $\frac{1}{500}$ in. in breadth. Two different kinds of glands are distinguished; some in larger numbers near the pyloric orifice are lined throughout with columnar epithelium, and are supposed to secrete mucus and are called *mucous glands.* The *peptic glands* have columnar epithelium at their mouths only, the rest of the gland being lined by two different sets of cells; those at the circumference of the tubule resting on the basement membrane, being oval in shape, are called *ovoid* or *peptic*, and another set, occupying a more central position, are cubical in shape and are termed *central cells.*

Delicate lymphoid tissue may be seen in places in the mucous membrane, resembling the solitary glands of the intestine.

The **Gastric Juice** is a thin, colourless acid fluid of S.G. 1,001 to 1,010, containing $\frac{1}{2}$ to 1 per cent. of solids in man. The daily amount varies, an average being 22–24 pints (13–14 litres). It contains:

1. Pepsin.
2. Peptones.
3. Hydrochloric acid (free).
4. Mucin.
5. Salts and water.

About $\frac{2}{3}$rds of the solid matter consists of peptones and pepsin and $\frac{1}{3}$rd of salts. Amount of free HCl = ·02 per cent.

Artificial gastric juice is best prepared by dissecting off the mucous membrane of the stomach of a pig, cutting it into small pieces and digesting it in glycerine for a few days, filtering and adding fresh mucous membrane. This may be repeated several times. Each time the glycerine will take up a fresh quantity. A little of the glycerine extract added to ·1 per cent. solution of HCl will form an active artificial gastric juice.

Action of gastric juice.—It has no action on starches, cane-sugar, or fats. It simply dissolves the connective tissue binding the fat vesicles together and setting free the fat, The characteristic action of gastric juice is its action on albuminous compounds converting them into the peptones. There are several different bodies included under the peptones, such as metapeptone, parapeptone, dyspeptone, but they closely resemble one another in properties. They differ from albumen in the following ways :—

1. They readily diffuse through animal membranes.

2. They are not coagulated by heat or nitric acid.

3. They are not precipitated by acetic acid and ferrocyanide of potassium.

They resemble albumen in being precipitated—

1. By tannic acid.
2. By lead acetate.

The part that pepsin plays in digestion is that of a ferment resembling the action of ptyalin in the saliva. Pepsin is not destroyed in the act of digestion, its digestive power appears to be infinite. Yet if more and more fibrin be added to artificial gastric juice, it will at last remain undissolved, the arrest of digestion being due to accumulation of the peptones and want of acid. For if the liquid be diluted and more acid added, digestion will recommence. The activity of the pepsin is greatest at a temperature of 30°–50° C. (90–112° F.) It is completely destroyed by boiling.

Digestion of the Stomach.—If a quantity of milk be introduced into the stomach of a rabbit and the animal killed an hour after and laid in a warm place for twenty-four hours, the walls of the stomach will probably be found digested. If a portion of the stomach of a dog be ligatured, the wounded stomach sewn up, and the dog allowed to live a few hours, the portion included in the ligature will be digested. The stomach itself is not digested during life, in consequence of the circulation through its walls of alkaline blood.

Secretion of Gastric Juice.—The stomach has two secretions, one thick, tenacious, and alkaline—the gastric mucus; the other, thin acid, and watery—the gastric juice proper. The former is secreted during fasting, while the latter is only secreted when food or fluid enters the stomach. Saliva or

alkalis, pepper, alcohol, excite the secretion of gastric juice. Their action is reflex: the vagus is probably the afferent nerve, which, acting on the medulla, inhibits the sympathetic and dilates the blood-vessels supplying the glands; the efferent impulses descending along the splanchnics.

Movements of the Stomach.—Food during digestion in the stomach is kept in motion by the peristaltic action of its walls. By the contraction of its muscular fibres currents are set up in its contents, the food travelling along the large curvature and returning by the lesser, while as digestion proceeds certain portions are passed through the pylorus into the duodenum.

Vomiting is a reflex act by which the contents of the stomach are expelled through the œsophagus and mouth. Very different circumstances may give rise to vomiting.

1. Irritation of the terminal fibres of the vagus from the presence in the stomach of certain substances as ipecacuanha, or a catarrhal state of the mucous membrance.

2. Irritation of the terminal fibres of different branches of the vagus or sympathetic, as in tickling the fauces, an inflamed peritoneum, an enlargement of uterus, as in the vomiting of pregnancy.

3. Direct irritation of the nervous centres, as in tumour of the brain or circulation through the nerve centres of certain substances, as apomorphia.

4. Vomiting may also be induced by disgusting smells, sights, or tastes.

The *afferent* nerves depend upon the cause; they may be vagus, sympathetic, first, second, &c.

The *nerve centre*, probably in the medulla.

The *efferent nerves*, phrenic, and nerves to abdominal muscles.

Mechanism of vomiting.—Peristaltic waves run from the pylorus to the cardiac end of the stomach, the cardiac aperture being firmly closed. Then a deep breath having been taken, the diaphragm fixed, and glottis closed, the cardiac sphincter is suddenly opened by fibres continuous with the longitudinal fibres of the œsophagus, the abdominal muscles contract, and the stomach being fixed by the diaphragm, its contents are expelled.

Structure of Small Intestine.—The small intestine commences at the pylorus and empties itself into the cæcum, and is about 20 ft. in length. It is divided into three portions, the *duodenum*, occupying the first 10 or 12 in., the upper $\frac{2}{5}$ths of the remainder being *jejunum*, and the lower $\frac{3}{5}$ths *ileum*.

It has four coats, serous, muscular, areolar, mucous. The **Serous** entirely surrounds the gut, except where the vessels enter. The **Muscular** consists of two layers, external *longitudinal* and internal *circular*. The **Areolar** is a loose connective tissue layer between the mucous and muscular. The

Mucous lines the intestine, and in the upper part of the jejunum is thrown into numerous transverse folds, called the valvulæ conniventes, which are permanent and extend about $\frac{2}{3}$rds of the way round the intestine. They increase the absorbing surface and help to delay the contents of the intestine. The mucous coat is separated from the areolar by a thin layer of muscular fibres, the muscularis mucosæ, and, like the stomach, is lined by columnar epithelium. It is provided with—

1. Villi.
2. Brunner's glands.
3. Crypts of Lieberkuhn.
4. Solitary glands.
5. Peyer's glands.
6. Lymphoid tissue and vessels.

1. The **Villi** are small processes of mucous membrane which extend from the pylorus to the ileocæcal valve, and give the inner surface of the intestine a velvety appearance. They are about $\frac{1}{40}$ to $\frac{1}{50}$ in. in length and are closely set together. They consist of an external layer of columnar epithelium, a basement membrane, a plexus of capillary vessels, a lacteal vessel, a few muscular fibre cells prolonged from the muscularis mucosæ and retiform tissue.

2. **Brunner's Glands** are small compound glands existing in the duodenum. They consist of clusters

of acini in connection with a minute duct, which opens on the surface.

3. The **Crypts of Lieberkuhn** are minute blind tubes which exist in every part of the intestine opening between the villi. They are lined by columnar epithelium and are $\frac{1}{120}$ in. to $\frac{1}{300}$ in. in length.

4. The **Solitary Glands** are small white bodies about the size of millet seeds scattered through the intestine. They consist of lymphoid tissue surrounded by a plexus of capillaries.

5. **Peyer's Glands** are groups of glands resembling the solitary glands in structure. They are situated for the most part in the lower portion of the ileum. The groups are oblong and placed lengthways in the intestine opposite to the attachment of the mesentery.

6. **Lymphoid** tissue is found in various places in the submucous tissue, in addition to that of the solitary and Peyer's glands.

Secretions poured into the Intestine.

BILE is an alkaline, golden yellow fluid of a bitter taste and S.G. 1018, and containing about 14 per cent. solid matter. If it remain long in the gall bladder it becomes viscid from the presence of mucus. From 30 to 40 ozs. are secreted in 24 hrs.

Composition :—

1. Mucin.
2. Bile-pigments.

3. Sodium salts of bile acids.
4. Cholesterin.
5. Leicithin.
6. Salts and Aq.

Bile-pigments.—The yellow colour of the bile of man and carnivora is due to *Bilirubin* ; the green colour of herbivora and that of man after oxidation is due to *Biliverdin.* A small quantity of *Biliprasin* may be present.

Gmelin's Test.—When strong yellow nitric acid is added to bilirubin or human bile on a white plate, a succession of colours is produced in the order of the colours of the spectrum—green, blue, violet, indigo, and red. If biliverdin be used the same result occurs, the first colour being blue. In applying the test to urine, care must be taken to notice the colours succeed one another in their right order, as the presence of indican may cause green, blue, and yellow colours.

Bilirubin may be prepared from dog's bile by acidulating with acetic acid and shaking with chloroform ; the chloroform dissolves the bilirubin, and on evaporation leaves the pigment of a red colour.

Biliverdin may be obtained by allowing an alkaline solution of bile to become green by exposure to the air. The bilirubin is oxidised and biliverdin formed, precipitating by HCl, dissolving in alcohol and evaporating. Bilirubin is believed

to be derived from hæmoglobin during its passage through the liver. It seems to be identical with the hæmatoidin found in old blood clots.

Bile acids are taurocholic and glycocholic acids. These acids are composed of cholic acid in combination with taurin and glycocine.

Pettenkofer's Test.—A small quantity of dilute bile is mixed with a few drops of sugar (cane sugar) and strong H_2SO_4 added; the solution becomes first cherry red, then of a purple colour. Some other organic substances give a similar colour, but may be distinguished by the spectroscope.

Preparation.—Bile is rubbed up with animal charcoal and dried at steam heat; it is thus rendered colourless. The bile acids are then dissolved out by absolute alcohol and precipitated by ether, as silky needles, which readily take up moisture and form a syrupy fluid.

Cholesterin can be obtained best from gall stones by boiling with alcohol and filtering while warm; white rhombic crystals of cholesterin form.

Uses of Bile.

1. Slight action in converting starch into sugar.
2. Assists in emulsifying and saponifying fats.
3. Assists in the absorption of fats.
4. Increases peristaltic action.
5. Prevents putrefactive changes in intestines.

The action that bile exerts in converting starch

into sugar and in emulsifying fat is slight. Mucous membrane, wetted with bile, allows minute globules of fat to pass readily through it, and in this way it aids the absorption of fat. It increases the peristaltic action of the intestine, thus aiding in the propulsion forwards of the contents of the intestine. It stimulates the contraction of muscular fibres of the villi emptying the lacteal, and forcing onwards its contents. It checks putrefactive changes. In jaundice, where the bile is prevented from flowing into the intestine, there is a tendency to constipation and flatulence.

Bile is being constantly secreted and accumulates till required in the gall-bladder. When the acid contents of the stomach enter the duodenum a reflex action is set up, leading to the contraction of the gall-bladder, and pouring out of bile into the intestine.

PANCREAS.

Structure.—The pancreas belongs to the class of compound racemose glands, and closely resembles the salivary glands, though of somewhat looser texture, the lobules being separated by more connective tissue.

Pancreatic Juice is a clear, viscid alkaline fluid resembling saliva, but of greater S.G., and containing about 2 per cent. of solid matter. About 12–16 oz. are secreted in 24 hours.

It contains—

1. Three ferments (pancreatin).
2. Albumen.
3. Mucin.
4. Salts and water.
5. Leucine and tyrosin.

Action.

1. It emulsifies and saponifies fat.
2. It converts starch into sugar.
3. It dissolves proteids, forming the peptones, and afterwards decomposing them into leucine and tyrosin.

The pancreatic juice acts vigorously on *fats.* On shaking with oil the fatty matter is quickly reduced into a state of minute division and suspended in the liquid. It decomposes fat, forming glycerine, and liberating fatty acids.

On *Starch.*—The pancreatic juice acts on starch with great energy, quickly converting the starch into grape sugar.

On *Proteids.*—Pancreatic juice acts in a somewhat similar manner as gastric juice. The process goes on most actively at a temperature of 100° F., and is permanently stopped by boiling. Its activity appears due to one or more ferments. Unlike gastric juice, it requires to be alkaline, there being about 1 per cent. of sodium carbonate present. In

the first stage the proteids are converted into peptones. If digestion go on, a part, at least, of the peptones are converted into tyrosin and leucine, and a peculiarly disagreeably smelling body, *indol*, is formed.

An artificial pancreatic juice can be made by making a glycerine extract of the gland.

Succus entericus is the secretion of the intestinal glands. It appears to act in a somewhat similar manner to pancreatic juice, converting starch into sugar, emulsifying fats, and dissolving proteids.

LARGE INTESTINE.

The *large intestine* consists of cæcum, colon, rectum.

Structure—resembles the small intestine, with some modifications.

The **Serous** coat completely surrounds the intestine in the transverse colon; is incomplete elsewhere.

The **Muscular** coat consists of two layers, the *longitudinal* being arranged in three flat bands, except at the rectum. One band is posterior, another anterior, and a third lateral or inferior in the transverse colon; along the latter the appendices epiploicæ are attached. These longitudinal fibres, by being shorter than the intestine, throw it into sacculi, which are marked off from one another

by constrictions where the circular fibres are most marked. The *circular* fibres form a thin layer over the intestine, and are best marked at the constrictions.

The **Mucous** membrane is lined with columnar epithelium, and is destitute of villi. It has numerous glands of Lieberkuhn and solitary glands, also retiform tissue.

The junction of the small and large intestine is guarded by a valve, and the termination of the rectum by the sphincter. But little, if any, digestive action goes on in the large intestine; the principal work done is absorption; the contents of the intestine become firmer and harder as they approach the rectum. The contents of the large intestines are acid, from the acid fermentations going on in the fæcal matters.

Movements of the Intestines.

If the abdomen of a recently killed animal be opened, the muscular fibres of the intestine will be seen alternately contracting and relaxing, but working down the intestine in waves so as to propel the contents downwards. This peristaltic action is increased by the presence of food or bile, or by irritation of the vagus nerve. It is checked by irritation of the splanchnic. The exact nervous mechanism is unknown, but it is probably automatic like the action of the heart. The movements of the large

intestine resemble those of the small; the fæces are lodged in the sacculi during the relaxation of the intestine.

Defæcation.—The sphincter is normally contracted under the influence of a nervous centre in the cord. The sigmoid flexure prevents the fæces from pressing too heavily on the rectum. The act of defæcation consists in an inhibition of the nervous centre in the cord which governs the sphincter, relaxation of the sphincter taking place. At the same time a deep breath is taken, the glottis is closed, the diaphragm and abdominal muscles contract, press upon the descending colon, and eject the contents of the rectum, the sigmoid flexure having previously become filled by peristaltic action.

Summary of Digestive Changes.

Mouth.—The food is crushed, mixed with saliva, and reduced to a pulp; a certain amount of starch converted into grape sugar and rendered slightly alkaline. Fats and proteids unaltered.

Stomach.—Contents rendered acid, conversion of starch into sugar ceases, connective tissue of fats dissolved, and fats set free. Proteids dissolved and peptones formed. The albuminous foods are dissolved for the most part, and a grumous mixture of peptones, liquid fats, and starches is formed, which is termed chyme, and is gradually passed through the pylorus into the intestine.

In the Intestine.—The chyme mixes with the bile, pancreatic, and intestinal juices, becomes alkaline, conversion of starch into sugar recommences, emulsifying of fat begins, and the undissolved proteids are converted into peptones. The diffusible peptones and salts enter the portal vein, the fat in a fine state of division entering the lacteals. In the large intestine the liquid chyme becomes more and more solid, is rendered acid by fermentative changes, and acquires the odour of fæces.

SECTION X.

ABSORPTION AND NUTRITION.

THE food must be acted upon by the various secretions of the alimentary canal before it can enter the blood-vessels or lacteals with which the walls of the stomach and intestines are well supplied.

The **Albuminous Foods** are crushed and reduced to pulp in the mouth, and converted into the peptones by the action of the gastric, pancreatic, and intestinal juices. By far the greater part of the peptones thus formed enter the capillary blood-vessels of the stomach and villi. Being diffusible through animal membranes, they pass through the walls of the capillaries by osmosis, enter the portal vein, and are conveyed to the liver. In the liver they are either split up into more oxidised bodies, as glycogen, urea, or kreatin, or are reconverted into albumen to assist in the nutrition of the tissues.

The **Starches** are converted into dextrose by the action of the saliva, pancreatic, and intestinal juices, and being thus rendered diffusible enter the portal

vein, and are conveyed to the liver. The liver probably converts the dextrose into glycogen, and stores it up till required to be oxidised for the production of heat and muscular energy.

The **Fats** are crushed and reduced to pulp in the mouth, and their fibrous tissue and vesicular envelopes dissolved in the stomach, so that the oily matters are set free. In the small intestine they undergo two different changes, which are effected by the secretions of the small intestine—

1. They are emulsified.
2. They are saponified.

The emulsification consists in reducing the fat into fine particles, small enough to readily enter the lacteals. The saponification consists in the formation of soaps: thus olein is decomposed, the glycerine being set free, and the oleic acid forming an oleate with sodium or potassium for a base.

Small quantities of the fatty matters find their way into the portal vein, but by far the major quantity enters the lacteals of the villi. The particles of fat enter the protoplasm of the columnar cells surrounding the villi, so that if these cells be examined during a period of digestion, they are seen to be distended with fat particles. They next pass into the retiform tissue of the villi, and thence into the lacteal, which commences in the villus. Finally, the fatty matters forming the chyle pass through

the mesenteric glands and into the receptaculum chyli and thoracic duct.

The exact forces in operation which determine the entrance of fat into the lacteals are not thoroughly understood. Animal membranes wetted with bile much more readily allow fatty matters to pass through them than membranes not so treated. The cells surrounding the villi, perhaps, exercise some selective power, as the glandular epithelium does in the convoluted tubes of the kidney. The fat once within a villus is driven onwards by the contraction of the muscular fibre present in the villi, compressing the lacteal and forcing onwards its contents; the aspirating power of the thorax supplying the *vis a fronte*. The fatty matters and albuminous materials present in the chyle are gradually, in part, converted during its passage through the mesenteric glands into the elements of fibrin and white blood corpuscles.

The food that has entered the body in the form of meat, starch, sugar, fats, after being digested passes into the blood-vessels in the form of peptones, fatty matters, and sugar. What processes must they undergo before they become formed tissue, such as muscle, nerve, tissue, or gland? But very little is known of such changes. Some of the albuminous and fatty matters are converted into white corpuscles and fibrin, probably through the action of the blood-glands, *i.e.*, spleen, lymphatic, lenticular, ton-

sils, thymus glands; the white corpuscles passing into red or exuding into the tissues to become transformed into the actual cells or fibres of the various tissues.

The albumen, fats, and sugars absorbed from the alimentary canal, pass out of the body at the kidneys and lungs as urea, salts, and CO_2. About the intermediate stages our knowledge is scanty.

Summary.

The portal vein absorbs	Peptones	(major part)
	Sugar	,,
	Salt	,,
	Soaps	,,
	Fats	(trace)
	Water	(major part)
The lacteal absorbs	Fats	(major part)
	Soaps	(small part)
	Peptones	,,
	Sugar	trace
	Salts	,,
	Water	(small part)

SECTION XI.

THE LIVER.

The liver is the largest gland in the body and weighs 50 to 60 ozs. In the fœtus and child it is larger in proportion to the body-weight than in the adult, being 1 in 20 to 30 in the child and 1 in 40 in the adult. The liver receives the blood of the portal vein and hepatic artery, the hepatic veins carrying away the blood from the organ. Its under surface is divided into lobes by five fissures.

The **Fissures** are the *transverse* where the vessels and nerves enter; the *longitudinal*, situated between the right and left lobes, is divided into two by the transverse fissure, the anterior part forming the *umbilical* fissure and containing the round ligament, and the posterior the fissure of the *ductus venosus*, containing the obliterated remains of the ductus venosus of the fœtus. The fissure of the *gall-bladder*, or rather fossa, makes the fifth.

The **Lobes** are, *right* and *left*, separated by the longitudinal fissure. The *lobulus quadratus* situ ated between the gall-bladder and longitudinal fis-

sure. The *lobulus Spigelii* between the fissure for the ductus venosus and inf. vena cava. The *lobulus caudatus* forms a sort of ridge extending from the base of the Spigelian lobe to the under surface of the right lobe.

Structure.—The liver has two coverings, the *serous* and *fibrous coats.*

The **Serous** is derived from the peritoneum, and is reflected round the organ, except where the vessels enter, and at the posterior border.

The **Fibrous** or **Connective Tissue** coat invests the whole gland, and at the transverse fissure becomes continuous with the fibrous tissue which accompanies the blood-vessels into the substance of the liver and forms the *capsule of Glisson.*

Hepatic Lobules.—On section of the liver its substance will be seen to be composed of closely packed bodies of rounded outline and of about $\frac{1}{12}$—$\frac{1}{20}$ in. in diameter. These lobules for the most part have a darkish red centre and lighter circumference, and in some animals, at least, are separated by a small quantity of connective tissue. The centre of the lobule is occupied by an *intralobular* vein, which collects the blood from the capillaries of the lobule and empties itself into the *sublobular*; the latter opens into the hepatic veins. The circumference of the lobule is surrounded by the *interlobular veins,* which are branches of the portal system; capillaries passing from the circumference to the centre of the

lobule connect the interlobular veins with the intralobular.

The **Hepatic Artery** enters the liver at the transverse fissure, accompanies the portal vein and ducts, and supplies the connective tissue of the liver.

The **Hepatic Cells** are packed in between the network of capillaries in the lobule. They are of rounded or polyhedral form, $\frac{1}{800}$—$\frac{1}{1000}$ in. in diameter. They have a yellow granular appearance and a well-marked prominent nucleus. They contain minute oil globules and glycogen.

The **Biliary Ducts** commence by a fine plexus of capillaries which run between and surround the cells. In a very thin section minute openings may be seen between the cells, which are the apertures of the capillary ducts. The larger bile-ducts are lined with columnar epithelium, their coats being formed of fibrous and elastic tissue with a mixture of unstriated muscular fibre.

The branches of the portal vein, artery, and duct accompany one another through the liver, the hepatic veins travelling by themselves.

FUNCTIONS OF THE LIVER.

The portal vein carries the blood which has circulated through the walls of the stomach and intestines, pancreas, and spleen. It is loaded with material absorbed from the contents of the stomach

and intestines. This blood is submitted to the liver before entering the general circulation. In its circulation through the liver it enters the interlobular plexus, travels through the capillaries of the lobule, coming into close relation with the hepatic cells, enters the intralobular veins, and finally the hepatic veins convey it to the inferior vena cava.

The liver in the adult has at least three functions—

1. Formation of glycogen.
2. Action on albuminous substances.
3. Secretion of bile.
4. In the fœtus it appears to give origin to white blood corpuscles.

1. **Glycogen or Amyloid Substance,** ($C_6H_{10}O_5$), is present in the cells of the healthy liver. When pure it is a white, tasteless, inodorous powder, insoluble in alcohol, soluble in water, forming a white opalescent solution. It closely resembles starch in appearance, but differs from it in being stained reddish-brown by iodine. Like starch it is readily converted into grape sugar by the action of dilute acids or ferments. Besides being present in the liver it is found in living muscle, white corpuscles of the blood, brain, placenta, and most tissues of the fœtus.

Preparation.—Fresh liver is boiled with strong solution of KHO, which dissolves the liver-tissue

and the glycogen, and on pouring it into alcohol the glycogen is precipitated tolerably pure. Another method consists in making a decoction of liver, precipitating the albuminous matters with potassic hydrarg. iodide and HCl, and afterwards precipitating the glycogen with alcohol (*see* p. 9).

Origin.—Glycogen is principally formed in the liver from the saccharine elements of the food.

$$C_6H_{12}O_6 - H_2O = C_6H_{10}O_5.$$

Grape sugar — water = glycogen.

Dogs fed on starch or sugar rapidly accumulate large quantities of glycogen in the liver; when fed on a purely animal diet very much smaller quantities are found. This appears to show that while glycogen is formed in small quantities from albumen, yet by far the major part originates from the saccharine elements of the food.

Destiny of Glycogen.—The fate of glycogen is uncertain. There can be no doubt it serves to store up material rich in C and H; but the exact manner in which it is utilised is not fully understood. Bernard maintained that it is gradually reconverted into sugar as required and oxidised in the capillaries of the body to maintain the heat or to supply muscular energy. He based this view on his analysis of the blood, which showed that a larger quantity of sugar existed in the hepatic than in the portal vein. He also found a greater quantity in the ar-

teries than in the veins, which seemed to suggest that sugar disappeared in the capillaries. Pavy maintains that the hepatic veins during life only contain a trace of sugar, and the arteries contain no more than the veins. He argues that the large quantities of sugar found in the hepatic veins after death are due to a post-mortem change of glycogen into sugar, and that during life only traces are to be found. He does not believe that glycogen is reconverted into sugar during life, and that if it were in any quantity, it would run off at the kidneys as in diabetes. The question is still *sub judice*. Glycogen is doubtless stored in the liver and is utilised in the system, either entering the blood as sugar or as glycogen in the white corpuscles, or in some other way. That it cannot enter the blood as sugar in any large quantity is certain, as, if it did, it would certainly be excreted in the urine as in diabetes. Bernard found 1 grm. per 1000 in the arteries, and 3—7 grms. per 1000 in the hepatic veins. This quantity seems too small to be of any great use in maintaining the energy of the body, and not improbably the glycogen may be utilised in some other way.

Diabetes is a disease characterised by an abnormal quantity of sugar in the urine. Its immediate cause is a rapid conversion of glycogen into sugar in the liver, depending probably on some disturbed innervation of the blood-vessels. It can be induced

artificially in animals by puncture with a needle of the vaso-motor centre of the medulla. This leads to dilatation of the blood-vessels of the liver, an increased supply of arterial blood, and an increased conversion of glycogen into sugar, which makes its appearance in the urine.

2. **Action on Albuminous Substances**—(*a*) Preparation of the peptones for assimilation. (*b*) Splitting up of various bodies into urea, &c.

(*a*) The portal vein contains the peptones which have been absorbed from the alimentary canal. These bodies disappear during their passage through the liver, being probably converted into serum-albumen.

(*b*) The liver probably splits up various substances, as albumen, kreatin, leucin, and tyrosin, the products being glycogen, urea, and uric acid. In certain diseases, as acute yellow atrophy of the liver, the urea in the urine is lessened, and tyrosin and leucin appear to take its place.

3. **Secretion of Bile.**—In all probability the pigments and biliary acids are formed in the liver and not merely separated from the blood. No trace of either of them has been found in frogs whose livers have been extirpated. To what extent the secretion of bile gets rid of effete matters from the system is uncertain. The biliary acids are in large part reabsorbed after having taken part in the digestion of the contents of the small intestine.

4. **Fœtus.**—The relative size of the liver in early fœtal life is about half the body weight; at full time it is about 1 in 18. It receives blood from two sources—(*a*) the umbilical vein, a portion of which escapes through the ductus venosus directly into the inf. vena cava; (*b*) the portal vein, which carries venous blood resembling that of the body generally. The functions of the fœtal liver differ from those of the adult, principally in its being a blood-making organ. After the formation of the placenta the umbilical vein brings various nutritive materials from the maternal system; the liver seems out of these materials to produce numerous colourless nucleated corpuscles which are poured into the blood. Probably before birth it ceases to do so, the spleen and lymphatic glands taking its place.

The biliary secretion (meconium) of the fœtus is purely excrementory in character.

SECTION XII.

THE KIDNEYS.

The kidneys are situated in the lumbar region opposite the last dorsal and two or three upper lumbar vertebræ. They are about 4 in. in length and weigh 4 to 5 ozs. each.

Structure.—On making a longitudinal section through a kidney the glandular structure will appear to be divided into two portions, (1) the outer or cortical portion, for the most part occupying the surface, except at the hilus; (2) the medullary portion, consisting of a number of pyramids separated from one another by cortical substance.

1. The **Cortical Substance** occupies the greater part of the gland, being $\frac{1}{3}$ to $\frac{1}{2}$ in. in depth at the surface, and extends into the centre of the gland between the pyramids. The cortical portion between the pyramids being termed the columns of Bertini. It is of a light red colour, and with the aid of a lens is seen to be studded over with bright red points, the *Malpighian bodies.* Besides these bodies, it

contains *convoluted tubes, the commencement of the collecting tubes, blood-vessels, and nerves.*

The **Medullary Portion** occupies the centre of the gland, and consists of 8–12 of the pyramids of Malpighi. These pyramids are surrounded at their bases and sides by cortical substance, while their apices project into the dilated portion of the ureter at the hilus, which forms the pelvis. They are of a purplish colour and marked with longitudinal striæ, and contain *collecting tubes, looped tubes of Henle, blood-vessels, and nerves.*

Urinary Tubules.—The *Malpighian bodies* are $\frac{1}{120}$ in. in diameter, scattered through the cortical substance of the kidney. They consist of a tuft of capillary vessels contained in a capsule formed by the dilated end of a urinary tubule, called the *Malpighian capsule.* The tuft of capillary vessels receives an arterial twig from an interlobular artery, and its efferent vessel forms a plexus surrounding the corresponding convoluted tube before joining an interlobular vein. The Malpighian capsule is formed of homogeneous membrane, lined by flattened epithelium, and joins a convoluted tube by a constricted neck.

The **Convoluted Tubes** commence as capsules in the cortex, twist upon themselves several times, and then descend in the medullary portion as a looped tube of Henle. They are lined by epithelium of a cubical or spheroidal shape, leaving a very small

lumen in the centre, and are surrounded by a capillary plexus.

The Looped Tubes of Henle, commencing at the termination of the convoluted tubes, descend for some distance, bend suddenly round and re-ascend again, the ascending and descending portions being parallel; they terminate in a portion of tube which is again convoluted. The looped tubes are narrower in calibre than the convoluted, and are lined by flattened epithelium. The second convoluted tube resembles the first portion, and empties itself into a collecting tube.

The **Collecting Tubes** are straight, and pass in bundles from the base of a pyramid to its apex. They are wider than the looped tubes, receive numerous other tubes, and are lined with columnar epithelium. A cut section of a pyramid shows numerous large apertures lined with columnar epithelium, the collecting tubes,—many small ones lined with flattened epithelium—the looped tubules of Henle, and the cut section of blood-vessels, the vasa recta.

Pyramids of Ferrein.—This term is applied in two senses, either to the portion of gland occupied by all the convoluted tubes which join one collecting tube, or to the bundles of collecting tubes seen in the cortical portion prior to their entrance into a pyramid.

Blood-Vessels.—The renal artery, on entering

the kidney, breaks up into numerous primary branches, which travel along the columns of Bertini, and are called the *arteriæ propriæ renales.*

These divide at the base of the pyramids and form arches with their neighbours; these arches give off (1) branches into the cortex termed the *interlobular arteries,* from which the afferent vessels to the Malpighian tuft arise; (2) branches downwards into the pyramids running between the bundles of collecting tubes and termed the *vasa recta* or *arteriæ rectæ.*

The **Renal Veins.**—The *venæ interlobulares* correspond with the arteries and receive some veins termed *stellate* from beneath the capsule, and also the small veins which receive the blood from the minute plexus surrounding the convoluted tubes.

The *venæ rectæ* run along the pyramids accompanying the corresponding arteries.

The *venæ propriæ renales* pass along the columns of Bertini after having been joined by the venæ interlobulares and venæ rectæ.

Pelvis and Ureter.—The ureters convey the urine to the bladder, their upper dilated portion forming the pelvis. The pelvis is divided into two or three primary divisions, and these again divide into shorter ones termed *calices* or *infundibula,* which receive the papillæ or apices of the pyramids of Malpighi. The collecting tubes open at the papillæ and discharge their contents into the pelvis.

The pelves and ureters are lined by transitional epithelium.

URINE.

The urine is a clear yellow fluid of S.G. 1020, of peculiar odour and acid reaction. It is constantly being secreted by the kidneys, and is collected in the bladder. On an average 52 ozs. (1,500 c.c.) are passed per diem. The solids amount to about 4 per cent. The principal constituents are the following, with their amounts, in 24 hours :—

Urea,	500 grs.,	or 33 grammes,	2·2 per cent.
Uric acid	7—8 ,,	,, ·5 ,,	·3 ,,
Kreatinin	14 ,,	,, ·9 ,,	
Hippuric acid	6 ,,	,, ·4 ,,	
Chlorides	105 ,,	,, ·7 ,,	

Sulphates
Phosphates
Sodium
Potassium } Smaller quantities.
Ammonia
Earthy salts
Pigment,&c.

Sources of Urea.—The greater part of the effete nitrogen of the body passes out of the system in the form of urea, a much smaller quantity in the uric acid, kreatinin, hippuric acid, and other minor constituents. The stages by which the albumins and

peptones are converted into urea are ill understood. It is not, indeed, certain whether the urea is simply excreted from the blood by the kidneys, or whether the epithelium of the convoluted tubes does not convert the kreatin present in the blood into urea, to be thrown off into the urine. The two most probable sources of urea are—

(1) From kreatin.
(2) From leucin and tyrosin.

(1.) Kreatin is found in the blood, and in most of the tissues of the body. Muscle contains from ·2 to ·4 per cent., while urea does not exist in muscle, and only to a very small extent, if at all, in the various organs. It is possible that kreatin represents the waste product of the albumin of the tissues. That in consequence of the changes necessitated by life there is a constant formation of kreatin in all the tissues of the body, and that this kreatin passes into urea in the liver or in the kidneys. The small increase of urea in the urine after active exertion would, on this view, represent an increased wear and tear, leading to an increased formation of kreatin and urea.

(2.) If the amount of nitrogenous food be increased in quantity, the amount of urea excreted in the urine is also increased. This would indicate that a certain part of the albumin of the food is split up into urea, &c., without its having taken

part in the formation of any tissue. Leucin and tyrosin are found in the small intestine, and are formed when pancreatic juice acts upon albuminous foods. It is probable that the leucin and tyrosin enter the portal veins, and are converted into urea in the liver. This is rendered the more probable from the fact already mentioned, that in acute yellow atrophy of the liver, leucin and tyrosin replace urea in the urine.

Amount of Urea.—About 500 grains of urea escape at the kidneys during 24 hours, but this amount varies according to circumstances. The amount being increased after large quantities of animal food, slightly after exercise, and also during fevers. The urea is diminished after vegetable food or fasting, and in certain forms of kidney disease.

Uræmia.—In certain conditions of the body, such as Bright's disease and in fevers, there is a greater accumulation of effete material in the body than can be carried off by the kidneys. Certain toxic effects, such as convulsions and coma, result. This is probably, though not certainly, due to the accumulation of kreatin in the blood.

Estimation of Urea.—There are two methods. (1) Liebig's; (2) Russell and West's.

(1.) Liebig's method depends upon the fact that urea forms an insoluble precipitate with mercuric nitrate. Before the estimation can be made, the sulphates and phosphates present are precipitated

by baryta water, and the liquid filtered. A certain quantity of the filtrate is taken, and a solution of mercuric nitrate of known strength (10 c. c. = ·1 grm. of urea) is dropped into the urine with frequent agitation: a white precipitate falls. From time to time as the mercuric solution is added, a drop of the liquid is tested on a white slab with a drop of solution of sodic carbonate, when all the urea is precipitated and free mercuric nitrate present in the solution; a yellow precip. occurs with the sodic carbonate. The amount of mercuric solution added is read off, and the corresponding amount of urea estimated. If great accuracy is required, the amount of Cl present must be estimated, and an allowance made in estimating the urea, as no precipitate of urea occurs until all the chlorine present has combined with the mercury.

(2.) Russell and West's method depends upon the fact that urea is decomposed by hypobromous acid, into CO_2, N, H_2O. The CO_2 is absorbed in passing through a solution of NaHO and the N measured in a graduated tube. The amount of N given off indicates the amount of urea present in the urine.

Uric Acid.—Some 7 to 8 grs. of uric acid are excreted daily in the urine, for the most part in the form of urates of potassium, sodium, or ammonium. The amount varies, being increased after animal diet, and in certain diseases, as gout. Its source is

uncertain, being like urea a waste product formed from the breaking up of nitrogenous compounds. It is probable that in certain derangements of the liver, uric acid is formed instead of urea. It represents a less oxidised form than urea.

Kreatinin.—Some 14 grains daily of kreatinin escape by the kidneys. Probably the greater portion of kreatin formed in the body has been converted into urea, a small amount being converted into the kreatinin which escapes with the urine.

Hippuric Acid.—Only about 6 grs: of hippuric acid are secreted daily in man; though a very much larger amount is present in the urine of the herbivora.

Pigments.—The yellow colour of the urine is due to several pigments, the nature of which is ill understood. *Indican* also occurs in the urine in variable quantities; it is known by the presence of a blue colour due to the formation of indigo, when strong acids are added to the urine.

Inorganic Salts.—These are numerous, the most abundant being sodium chloride, smaller quantities of potassium, magnesium, calcium in the form of phosphates, sulphates, chlorides, and carbonates. The amount and variety of the salts in the urine differ according to the food taken. The alkalies being increased during a vegetable diet, the urine becoming alkaline, the earthy salts being increased when animal food is taken.

Secretion of Urine.

The Malpighian bodies, and that portion of the urinary tubules known as the convoluted tubes, are both engaged in the separation of the urine from the blood. The Malpighian bodies, as before explained, consist of a tuft of capillaries fitting inside a capsule communicating with the convoluted tubes, and are probably engaged in secreting the greater part of the water and inorganic salts of the urine, the process consisting in a simple transudation depending upon the pressure in the capillary tuft.

The convoluted tubes are lined by glandular epithelium and are surrounded by a plexus of capillaries. The epithelium lining them appears to exercise a certain selective influence in secreting the urea and uric acid and pigment, or possibly actually effect the change of kreatin into urea. These substances, having been separated from the blood and entered the urinary tubules, are washed down by the water and salines transuding through the capillary tufts into the capsule above.

The amount and character of the urine largely depends upon the blood-pressure in the capillaries of the kidney. If the pressure be increased larger quantities of water will be passed, and under certain circumstances, as in nephritis, albumen, blood, and fibrinous material. The blood-pressure will depend upon the vaso-motor nerves distributed to the renal

arteries, also on the state of the general circulation, as well as on the action of the heart. Section of the renal nerves causes dilatation of the renal arteries, increase of capillary pressure, and an increased secretion of the watery constituents of the urine.

Section of the spinal cord below the medulla, causes a general dilatation of the blood-vessels throughout the system, and consequent lowering of the blood-pressure in the renal arteries, and almost complete arrest of the secretion of urine.

Stimulation of the divided cord below the medulla produces a similar result, though not so marked, by causing general constriction of the arteries, including the renal, the increased tension in the general arteries not being sufficient to overcome the resistance offered by the constricted renals.

SECTION XIII.

THE DUCTLESS GLANDS.

THE *spleen, lymphatic* glands (including *lenticular glands* of alimentary canal and *tonsils*), *supra-renals, thymus* and *thyroid*, form the ductless glands. The *pituitary, pineal,* and *coccygeal* bodies are not in any sense glands, nor have they probably any analogous function to them.

SPLEEN.

The spleen is the largest and most important of the ductless glands. It is a soft, red, vascular organ, situated at the cardiac end of the stomach beneath the diaphragm. It has two coats, a serous and fibro-elastic.

The **Serous** closely invests its surface, except at the hilus and at the spot where it is reflected to the stomach and diaphragm.

The **Fibro-elastic** or **Tunica propria** is a strong capsule surrounding the organ, and passing into its substance at the hilus forms a sheath for the vessels and trabeculæ, which divide the gland into spaces

occupied by the pulp. It consists of white and yellow fibrous tissue, and non-striated muscular-fibre, the latter well marked in the pig and dog, but more scanty in man. The capsule is highly elastic, and capable of great distension.

The **Spleen Pulp** occupies the spaces between the trabeculæ, is of a dark red colour, and semi-solid consistence. The pulp, when examined in thin section beneath the microscope, is seen to consist of a network of branched connective-tissue corpuscles, the branches joining one another, and forming a fine retiform tissue. Many of these connective-tissue corpuscles contain a clear oval nucleus, and some contain yellowish pigment granules, possibly derived from the blood-corpuscles. The spaces between these branched cells contain red and white blood corpuscles, the white being in larger proportion than in ordinary blood.

The **Splenic Artery** enters the spleen by dividing into six or more branches, which ramify in the interior, supported by the trabeculæ, and break up in the pulp into fine branches. The small arteries terminate in capillaries, the walls of which eventually are lost, their cells becoming gradually transformed into the connective-tissue corpuscles of the pulp, and their contained blood wanders freely through the retiform tissue of the pulp. The minute veins arise in a manner similar to that in which the arteries terminate, and eventually empty

themselves into the splenic vein. Thus the blood, in its course through the spleen after leaving the arteries, wanders freely through the pulp before entering the veins.

The **Malpighian Corpuscles** are small bodies, about $\frac{1}{60}$ in. in diameter, and may readily be seen in the child's spleen as small white dots scattered thickly over the cut surface. They are seated upon the small arteries, their sheath being continuous with that of the arteries, though in man the sheath is not very distinct, and the tissue of the Malpighian body is continuous with that of the spleen pulp. In structure they consist of lymphoid tissue, the leucocytes being densely packed in a fine network. A small artery enters their substance.

Functions.—The exact functions performed by the spleen in the animal economy are ill-understood; the most certain are the following:—

(1.) During digestion the spleen becomes congested, the arteries and trabeculæ being relaxed, the elastic tissue yielding, and the organ containing more blood. This has been attributed by some to the necessity of having an excessive quantity of blood in the portal system during digestion, the spleen acting as a reservoir, but more probably it is connected with important changes going on in the spleen pulp.

(2.) The spleen is a source of white blood corpuscles to the blood; the splenic vein containing 1

white to 60 red, whereas in ordinary blood it is 1 to 400. The blood in passing through the pulp comes into close relation with the lymphoid tissue, and new corpuscles are formed.

(3.) Red corpuscles are probably broken up and disintegrated in the spleen. The spleen pulp shows yellowish granular matter, which may be derived from the hæmoglobin of the red corpuscles. This colouring matter may be converted into pigment in the liver.

(4.) The conversion of white corpuscles into red has been attributed to the spleen, but this is very uncertain.

LYMPHATIC GLANDS

Have already been referred to (p. 86).

SUPRARENALS.

The suprarenals are two small bodies of a somewhat triangular shape which surmount the kidneys.

They are about $1\frac{1}{2}$ in. in height and $1\frac{1}{4}$ in. in width. They weigh 1 to 2 drms. each.

Structure.—They are invested by a fibrous coat which surrounds each organ. On section, they are seen to consist of a *cortical* portion forming the greater part of the organ, of firm consistence and yellow colour, and a *medullary* portion, which is soft and pulpy, and of a brownish black colour.

The **Cortical Portion** consists of a fibrous stroma, in the meshes of which are cells arranged in columns

which radiate from the centre of the gland. The cells are granular, yellow, and nucleated, and are about $\frac{1}{1500}$ in. in diameter, and contain minute oil globules. Small arteries run between the columns.

The **Medullary part** is separated from the cortical by a layer of connective tissue, and is best marked in the suprarenals of young animals. It consists of a stroma, in the meshes of which are enclosed groups of cells which are coarsely granular, have no oil globules, and some of them are branched.

Nerves.—Bundles of nerves run through the cortex, and form a network in the medullary part.

Function.—Nothing is known for certain regarding the function of these bodies. The most interesting point is their connection with Addison's disease, in which tuberculosis of the suprarenal capsules is accompanied by a bronzed tint on the skin, vomiting, and progressive emaciation. Some maintain, that like the spleen, they exercise some influence in the elaboration of nutritive material in the blood. Others believe them to be connected with the nervous system, and the cells of the medullary portion to be nerve cells.

THYROID GLAND.

The thyroid gland consists of two lateral lobes situated on either side of trachea and larynx, and joined by an isthmus which crosses in front of the trachea at the 3rd and 4th rings. It is soft, of a

reddish colour, and weighs from one to two oz., and is larger in the female than male.

Structure.—It is invested by a layer of fibrous tissue which connects it with surrounding parts. It is composed of a number of closed vesicles, which are from $\frac{1}{800}$th in. in diameter to the size of a millet seed. Each vesicle is surrounded by a plexus of capillaries, is formed of a basement membrane, and lined by a single layer of epithelium. They normally contain a clear fluid, but often a material of jelly-like consistence. The organ is very vascular, receiving a large blood supply.

Function.—Nothing is known concerning the function of the thyroid body. There are no facts to support the theory that, like the spleen, it pours white corpuscles into the blood. It is enlarged in certain diseases, as in *goître*, common in Derbyshire and the valleys of Switzerland, and seems to be connected with the constant use of water impregnated with magnesian limestone; and in *exophthalmic goître*, a disease characterized by enlarged thyroid prominence of the eyeballs, and irregular action of the heart.

SECTION XIV.

NERVOUS SYSTEM.

THE NERVOUS SYSTEM is divided into two great divisions :

1. The Cerebro-spinal.
2. The Sympathetic.

1. The CEREBRO-SPINAL includes the brain, spinal cord, certain ganglia, motor and sensory nerves. The motor nerves are supplied to the striated or voluntary muscles, the sensory are distributed to the organs of sense, skin, and other parts endowed with sensibility. The nerve-fibres are mostly of the medullated kind.

2. The SYMPATHETIC consists of a series of ganglia and nerves, which supply the involuntary muscular fibre of the uterus, stomach, intestines, ducts, and blood-vessels. The sympathetic system has a less symmetrical arrangement than the cerebro-spinal; the nerves are of a reddish colour, and are composed, for the most part, of non-medullated or grey fibres.

These two sections of the nervous system are

intimately connected with each other, indeed they can hardly be regarded as distinct systems; the sympathetic may be regarded as that portion of the nervous system which supplies the internal organs and blood-vessels.

STRUCTURE OF THE NERVOUS MECHANISM.

I. Purely conducting organs, nerves.
II. Terminal end organs.
III. Central organs, as brain, cord, ganglia.

1. **Nerves.**—Nerves consist of bundles of nerve fibres bound together by a common connective tissue sheath, called the epineurium. This sheath contains fibres, blood-vessels, numerous connective tissue corpuscles, and has also lymph spaces.

If a transverse section of a large nerve, say the sciatic of a dog, be examined under the microscope, bundles of nerve fibres will be seen, each bundle surrounded by its sheath (perineurium), and the bundles will be seen to be connected together by a coarser tissue containing vessels, and often adipose tissue (epineurium). Between the nerve-bundle and the perineurium is a space, which is lined by flattened cells, and forms the lymph space; it communicates with the lymphatics of the nerve. The nerve tubules themselves are surrounded by fine connective tissue, containing numerous cells continuous with the perineurium.

Each nerve tubule will be seen in cross section

to consist of a central dot (axis cylinder), surrounded by a clear material that does not stain (medullary sheath), enclosed by a ring (primitive sheath).

Nerve tubules are of two kinds :—

(*a*) Medullated.
(*b*) Non-medullated.

(*a*) The **Medullated Nerves** are present, for the most part, in the cerebro-spinal system. They vary very much in size, being from $\frac{1}{5000}$ to $\frac{1}{100000}$ in. in diameter. When examined shortly after death, they appear as translucent, homogeneous threads with a single contour. On addition of various reagents, it can be made out that a medullated nerve consists of:

(1) Primitive nerve sheath.
(2) White substance of Schwann.
(3) Axis cylinder.

(1.) The *primitive nerve sheath* or neurilemma is a thin hyaline membrane which surrounds the nerve. In this sheath annular constrictions may be seen at intervals, which project into the nerve tubule as far as the axis cylinder; these constrictions are called the nodes of Ranvier. On the inner surface of the sheath are nuclei surrounded by finely granular protoplasm; these nuclei do not belong to the neurilemma.

(2.) The *medullary sheath* is semi-fluid during life, but coagulates after death. It consists of fatty

matters, soluble in ether, and when squeezed out of the primitive sheath appear like bright drops with a double contour. When the white substance has coagulated, the nerve, which immediately after death appears to have a single outline, becomes dark-bordered. According to Klebs, the axis cylinder and medullary sheath are separated by a narrow space, called the *periaxial space*, containing a cement substance. The medullary sheath is stained black by osmic acid.

(3.) The *Axis cylinder* is a narrow thread which runs through the centre of the nerve. It is albuminous in nature, is continuous with the poles of nerve cells, and stains with carmine, logwood and chloride of gold.

Medullated nerves when coming near their terminations lose their medullary sheath. Some medullated nerves, especially in the optic nerve, possess more or less regular varicose enlargements.

(*b*) **Non-medullated Nerves** consist of—

(1) Primitive nerve sheath.
(2) Axis cylinder.

They closely resemble the medullated nerves, but the white substance of Schwann is wanting. They vary in size $\frac{1}{3000}$ to $\frac{1}{6000}$ in. in diameter. They are present for the most part in the nerves of the sympathetic system, but they are also present in the cerebro-spinal nerves.

TERMINATIONS OF NERVES.

I. Sensory Nerves end in—

1. Networks or plexuses.
2. Special Organs
   - (*a*) Pacinian bodies.
   - (*b*) End-bulbs.
   - (*c*) Touch corpuscles.
   - (*d*) Rods and cones, taste-buds, &c. &c.

II. Motor Nerves—

1. Striated muscle.
2. Non-striated.

I. **Sensory Networks or Plexuses.**—The nerve bundles as they approach their terminations divide and re-divide till the branches consist of only one or two tubules. In the *skin* and *mucous membrane*, when the nerves are approaching the surface epithelium, they lose their medullary sheath, join together, and form the *subepithelial* plexus. From this plexus fine fibrils are given off, which, according to Klein, pierce the rete mucosum, and end beneath the cells of the horny layer, or, according to some, in the epithelial cells themselves.

In the *cornea* there are two terminal plexuses, superficial and deep. The superficial forms a subepithelial plexus, which gives off minute fibrils, which end in the interstitial substance *between* the epithelial cells on the surface. The deep plexus is situated in the substance of the cornea ; some of the fine fibrils are said to end in the corneal corpuscles.

2. **Special Organs**—(*a*) **Pacinian Bodies** are ovoid in shape, about $\frac{1}{10}$ to $\frac{1}{25}$ in. in diameter, and are found attached to the digital, plantar, pudic, infraorbital nerves and mesenteric nerves of cat. These bodies consist of a number of concentric membranes placed inside each other, enclosing a clear space in the centre, which contains the termination of a nerve. Each capsule consists of a hyaline membrane marked with fine transverse fibres, and lined on their inner surface by a layer of endothelial cells. There is no fluid between the layers, as sometimes described. The central clear mass contains a hyaline matrix and an axis cylinder, the sheath and white substance of Schwann being lost before the nerve enters the clear space. Besides the nerve a minute artery enters the Pacinian body, and distributes capillaries between the capsules.

(*b*) **End Bulbs** exist in man in the conjunctiva, lips, mucous membrane of mouth, soft palate, genital organs. They are about $\frac{1}{600}$ in. in diameter, and consist of an ovoid corpuscle, in which a medullated nerve fibre terminates. They are surrounded by a capsule continuous with the perineurium surrounding the nerve. The matrix is a granular mass containing oval nuclei. The nerve loses its medullary sheath and ends in a budlike process.

(*c*) **Touch Corpuscles** exist in the skin in the papilla or beneath the epithelium in other situations. They are about $\frac{1}{300}$ in. in diameter, and consist of

a capsule, with a core of granular matter, which receives an axis cylinder after a more or less tortuous course. (*d*) Other end organs, as the rods and cones, taste-buds, organ of Corti, will be described in connection with sight, taste, &c.

II. **Terminations in Muscles.**—(1.) Non-striated muscles are supplied with non-medullated nerves, which form plexuses. These plexuses give off the primitive fibrils which run in the interstitial substance between the cells; and, according to some, give off fine branchlets, which enter the nuclei of the cells themselves.

(2.) **Striated Muscle.**—Nerves surrounded by their perineurium run in the connective tissue, forming the sheath of the muscle. Branches are given off which form a plexus, branches containing two or three nerve tubules form an intermediate plexus for the supply of the smaller bundles of fibres. The nerve tubules enter the muscular fibres, the primitive sheath becomes fused with the sarcolemma, while the axis cylinder loses its medullary sheath and passes through the sarcolemma. The axis-cylinder ends on the surface of the muscle substance embedded in a flat granular mass, the *end-plate* of Kuhne. The end-plates viewed in profile form Doyère's prominences.

III. Structure of the Central Organs.

The **Grey Matter** is present on the surface of the convolutions of the cerebrum, cerebellum, in the central parts of the spinal cord, corpora striata, optic thalamus, corpora quadrigemina, ganglia, &c.

It consists of: 1. Nerve cells. 2. Nerve tubules. 3. Pigment. 4. Blood vessels. 5. Neuroglia.

White Substance consists of: 1. Nerve fibres. 2. Blood vessels. 3. Neuroglia.

1. **Nerve Cells** are small, rounded or branched bodies, destitute of a cell wall, formed of finely granular protoplasm, in reality consisting of a fine network of fibrils. Each cell contains a nucleus, having a well-defined capsule, fine network, and a nucleolus. The cells are surrounded by a perivascular space. In shape they are *apolar*, *unipolar*, *bipolar*, or *multipolar*, according to the number of processes they possess. Each process is continuous with the axis cylinder of a nerve. *Apolar* cells are found in the sympathetic ganglia, *unipolar* in the cerebellum and cord, *bipolar* in the ganglia on the posterior roots of the spinal cord, *tripolar* in the grey matter of the cerebrum, and *multipolar* in the spinal cord.

Neuroglia.—This name is given to the framework of the grey and white matter of the cerebrum, cerebellum, and cord. It consists of—(1) Branching

nucleated cells. (2) A fine network of fibrils connected with the branches of the cells. (3) A homogeneous or finely granular matrix. The neuroglia forms a material in which the nerve cells and fibres are embedded; it slightly varies in different parts of the nervous system.

The white matter is distributed in various places in the brain and cord, connecting the grey matter of different parts. The nerve fibres are medullated, but have no primitive sheath. They vary in size, often possess varicose swellings, due to an accumulation of fluid between axis-cylinder and medullary sheath.

GANGLIA.—These consist of rounded or elongated bodies found in various situations in connection with nerves. They are present in the following places:

1. On the posterior roots of the spinal nerves; on the roots of the 5th, 7th, vagus, glosso-pharyngeal; in several other situations, as the ophthalmic, Meckel's otic, and lenticular ganglia.

2. In connection with the sympathetic system, (*a*) forming a series by the side of the vertebral column; (*b*) in numerous other places in the walls of the heart, intestines, uterus, and in connection with the plexuses.

They consist of grey matter, the nerve cells having mostly a pyriform, or rounded outline.

PROPERTIES AND FUNCTIONS OF NERVES.

1. **Nutrition.**—Nervous matter receives a rich supply of blood; the network of capillaries in the grey matter is closer than in the white. The nerve cells receive their nourishment from liq. sanguinis which has exuded from the vessels. Active nerve cells absorb O and eliminate CO_2. Some nerve centres exercise an important influence over the nutrition of certain nerves; thus, if a motor nerve of the spinal cord is cut off from the grey matter in the anterior cornua, it undergoes fatty degeneration, and the muscle it supplies becomes atrophic. If a sensory nerve is divided, the part attached to the posterior ganglion remains normal; that part which has been separated from the ganglion degenerates.

When a nerve is cut in a mammal, the ends often reunite in a few weeks.

2. **Nervous Excitability and Conductivity.**—Nerves, like muscles, are irritable or excitable. If one end of a nerve is irritated by the application of a stimulus, such as the application of heat, the electrodes of a battery, or by other means, the irritation or excitation is conveyed along the nerve to its farthest extremity. If the nerve is attached to muscular fibre, a *contraction* is produced; if the nerve ends in a sensory centre, a *sensation* is produced, or the secretion of a gland poured out if the nerve terminates there. The nerves receive im-

pressions through the medium of certain terminal organs, as the touch corpuscles, rods and cones of retina, and convey the impression produced to a certain sensory centre, and a sensation is felt, or they receive an impulse from certain motor centres, and convey the impulse to their terminations in the end plates of the muscles and a muscular contraction ensues.

If the nerves are too frequently excited they become fatigued, and a certain amount of repose is necessary for them again to conduct impressions.

There are several methods of measuring the velocity of the nerve current. The ordinary method in motor nerves of frog consists in applying the electrodes directly to the *muscle*, and measuring the time that elapses before the contraction, the contracting muscle recording its movements by means of a lever on a revolving drum (a chronograph marking time); then, if the electrodes be applied to the *nerve*, at some distance from the muscle, and the time again measured, it is evident that the difference between the two will be the time that the nerve current took to travel through the nerve.

The velocity of the nerve current has been calculated to be about 80 ft. per sec. in the frog, and 100 to 120 ft. per sec. in man, though some placed it at 200. Sensory impressions in man have been measured in the following way:—Arrangements are

made for a person to give a signal—the moment he feels a prick, say, on his great toe—and the time noted between the prick being administered and the signal given. Another experiment is made in the same way by pricking a point nearer the brain, say the knee, and the time measured. The difference between the two will be the time the impression takes to travel from toe to knee. It has been found that the velocity is about the same as in motor nerves—110 to 120 ft. per sec. This method is, however, open to many objections.

3. **Electrical Phenomena of Nerves.**—Electrical currents are present in living nerves. If a piece of a nerve be cut out and placed upon the electrodes of a galvanometer, so that the surface of the nerve touches one electrode and the cut end the other, a current will be observed to pass from the surface through the galvanometer to the cut end. The nerve currents exactly resemble the muscle currents. When the nerve is excited there is a diminution or negative variation of the normal current.

Electrotonus.—If a constant current be passed along a nerve, the nerve is thrown into a peculiar state termed electrotonus. If the current travel in the direction of the natural nerve current, the latter is increased; if in the contrary direction, it is diminished.

While a portion of nerve is traversed by the

constant current, its properties are to some extent altered; the portion in the neighbourhood of the positive pole is said to be in an *anelectrotonic* state, while the portion of nerve in the neighbourhood of the negative is in a *cathelectrotonic* state. The position of the neutral point between the two, varies with the strength of the current passing through the nerve. With a current of *medium* intensity, the neutral point is midway between the poles; with a *weak* current the neutral point is nearer to the positive than the negative; with a *strong* current the neutral point is nearer the negative than the positive. When a nerve is in the anelectrotonic state, its natural nerve currents are increased, but its excitability and conductivity are diminished. When in the cathelectrotonic, its natural nerve current is diminished, but its conductivity and excitability are increased.

Pflüger's Law of Contraction.—When a constant current of medium strength is passed along a motor nerve, no effect is produced upon the muscle, except on opening and closing the current. The contraction of the muscle is influenced (1) by the direction, (2) by the strength of the current—that is, the strength of the contraction on making and breaking contact varies not simply according to the strength of the current applied, but also to the direction, whether the current is passed downwards in a direction from the spinal cord to the muscle, or in

an upward direction from the muscle to the cord. The following is a brief statement of the facts :—

Strength of Current	Descending		Ascending	
	Make	Break	Make	Break
Very weak	C	R	R	R
Weak	C	R	C	R
Medium	C	C	C	C
Strong	C	R	R	C

C = contraction. R = rest.

From this table it will be seen that, if either a weak or a strong current is passed along a motor in a downward direction, there will be a contraction at making only. With a strong ascending current there is a contraction on breaking only.

Functions and Classification of Nerves.

Nerves are divided according to their functions into—I. *Efferent*; II. *Afferent.*

I. The **Efferent** nerves are divided according to their uses—(1) *Motor* fibres, at the peripheral end of which is a muscle. (2) *Vaso-motor* fibres, which supply the muscular fibres of the blood-vessels. (3) *Secretory*, which are supplied to the epithelium cells of glands. (4) *Inhibitory* nerves, which modify the action or inhibit the centres to which they are supplied. (5) *Connecting* motor centres.

II. The **Afferent** nerves may be divided into—(1) *Sensory*, which convey sensations of pain or

pleasure, hearing, sight, touch; and (2) Connecting sensory centres.

Eccentric Reference of Sensations.—The mind refers the origin of every sensation that reaches it through a sensory fibre to the end organ of that fibre, even though stimulation has been applied to the trunk of the nerve. Thus, persons whose arms or legs have been amputated often feel sensations which they refer to their fingers or toes. Any stimulation of the optic nerve, mechanical or electrical, the mind refers to the action of light upon the retina.

Functions of Terminal Organs.—Probably all nerves end at their peripheral distribution in some form of terminal organ. The optic nerves are connected with the rod and cones of the retina, and other sensory nerves are connected with taste-bulbs, olfactory corpuscles, tactile corpuscles, or epithelium. Motor nerves end in end-plates inside the sarcolemma. Light will not affect the optic nerves, except through the medium of the rods and cones; sensations of touch will not be received at the brain if the skin is stripped off the fingers. The terminal organs seem to play the part of receivers of impressions, and awaken an excitation in the nerves connected with them.

Functions of Nerve Centres.

Groups of nerve cells, which form the nerve centres, are arranged in the body in two systems,

the cerebro-spinal and the ganglionic system, consisting of ganglia scattered through the body. The centres may be classified in various ways, according to their functions; thus, on the surface of the brain there are *motor* or *discharging* centres, *centres of special sensations* as of *sight, touch*; in the medulla there are *inhibitory* and *accelerating centres.* They all however fall into two great divisions, though it is not always easy to say to which class they belong. These are *automatic* centres and *reflex* centres.

Automatic Actions are actions which are evoked in the absence of any influence external to the nerve centre. The brain is the seat of the higher automatic centres, those connected with volition and intelligence. In the medulla the respiratory centres, cardiac centres, vaso-motor centres, are in a certain sense automatic. So are also the intrinsic ganglia of the heart, and the small ganglia found in the walls of the intestines. At the same time it must be remembered that many of the centres enumerated above are influenced by sensory or afferent impulses, and are reflex as well as automatic; indeed, some would deny them their automatism, and believe that no motor impulses can be generated, in the absence of all eccentric influences.

Reflex Actions.—For reflex actions the following apparatus is required:

(1.) A sensory surface in connection with an afferent nerve.

(2.) A group of nerve cells.

(3.) An efferent nerve connected at its central end with (2) and by its peripheral end, with some muscle or muscular tissue. The sentient surface or end organ being excited, the impulse travels along the afferent nerve to the centre, and is reflected from the centre along the efferent nerve to the muscle.

Reflex actions may take place without evoking consciousness, and may be entirely beyond the control of the will. Such an act is the contraction of the pupil under the influence of light. Some other reflex actions we are more or less conscious of, and can control or modify by our voluntary powers, such as the act of respiration or coughing. Some acts we are conscious of, but cannot control, as sneezing, vomiting. The character of the efferent impulses may either depend upon the intensity of the stimulus applied, or the energy stored up in the nerve-centre, and be out of proportion to the intensity of the stimulus. Thus, in a brainless frog, if the skin of the flank be irritated, a slight movement of the muscle beneath follows; if the stimulus is increased, the hind leg of the same side endeavours to remove the irritation; subsequently if the irritation be still greater, all the muscle of the body, including those of the limbs of opposite side, will endeavour by their actions to get rid of the source of irritation.

On the other hand the irritation caused by the presence of a hair in the glottis will call into play a large number of expiratory muscles, though the irritation would seem to be so small in amount.

The following instances of reflex acts may be taken as examples :—

(1.) Contraction of iris. A.N. = optic. N.C. = corpora quadrigemina. E.N. third.

(2.) Winking. A.N. = fifth or optic. N.C. = corpora quad. E.N. seventh.

(3.) The first respiration after birth from impression of cold on the skin. ANs. = sensory of cord. N.C. = medulla. ENs. phrenics, intercostals, &c.

(4.) Vomiting from tickling fauces. ANs. = glossopharyngeal, fifth. N.C. medulla. ENs. phrenics, Ns. to abdominal muscles, vagi.

(5.) Sneezing from a draught of cold air. A.N. = nasal branches of fifth. N.C. = medulla. ENs. intercostals, Ns. to abdominal muscle, phrenics, &c.

Reflex actions are also seen in various forms of disease or abnormal conditions, such as vomiting from cerebral tumour, vomiting of pregnancy, grinding of teeth from irritation of worms, palpitations of heart, &c.

Strychnine excites reflex actions by stimulating the centres. Bromide of potassium depresses the centres and diminishes reflex sensibilities.

SPINAL CORD.

The SPINAL CORD has its upper limit at the margin of occipital foramen, and extends downwards to the lower border of the first lumbar vertebra. It is fifteen to eighteen inches in length, and presents two enlargements, the cervical and lumbar. It ends below in the cauda equina, which consists of a bundle of nervous cords.

Structure.—The cord consists of—

(1) The grey matter in the centre.
(2) The white substance externally.

(1.) The **Grey Matter** consists of two crescents, joined by a commissure, in the centre of which is the central canal of the spinal cord. The anterior cornua of the crescents are rounded, and connected with the anterior roots; the posterior are more pointed, and connected with the posterior.

The cells of the anterior cornua are large, $\frac{1}{400}$th to $\frac{1}{200}$th inch in diameter, are multipolar, and contain nuclei and pigment; some of the cells are small and round. In the posterior cornua, the cells are collected into two groups, the *substantia gelatinosa* at the extremity of the cornua, and the *posterior vesicular column* situated on the inner side of the cornua near the commissure. Many of the cells in the posterior cornua are destitute of processes.

(2.) The **White Matter** is divided into two halves

by the anterior and posterior fissures. Each lateral half is again divided by two lateral fissures, which are merely grooves along the line of attachment of the anterior and posterior branches into an anterior, lateral, and posterior column. The white substance on section, and examination by a high power, displays the cut ends of the nerve fibres presenting small rings with a dot in the centre. The dot representing the axis-cylinder, and the surrounding space the white substance of Schwann.

Functions of the Cord.

(1.) As a conductor of impressions and impulses.
(2.) As a series of nerve centres.

The Cord as a Conductor.

(1.) The spinal cord forms the channel of communication between the brain and nerves passing to the periphery of the body. The exact path of the motor and sensory nerves is not definitely settled, as there is still a difference of opinion among experimenters.

Motor Path.—The motor impulses travel along the *lateral* columns of the cord, their decussation taking place in the medulla only. The fibres pass from the anterior pyramid of one side to the lateral column of the opposite side, and join the *anterior* roots of the spinal nerves.

Sensory Path.—The sensory nerves pass into

the cord by the *posterior root;* the sensations of pain, temperature, &c., travel upwards along the central grey matter, those of touch along the posterior columns; the decussation taking place immediately the nerves enter, the sensation travelling up the opposite side of the cord.

According to Ludwig the sensory impressions travel along the lateral columns with the motor, the anterior and posterior columns being simply commissural, connecting different portions of the cord together.

If one lateral half of the spinal cord be divided there will be loss of motion on the *same* side, and loss of sensation on the *opposite.*

Reflex Functions of the Spinal Cord.—Frog. If the spinal cord of a frog be divided immediately below the occipital foramen, the frog will retain its usual sitting attitude, with the exception of sinking down into a somewhat less erect position, the fore limbs being more spread out. It will exhibit no respiratory movements. If one of the hind legs be pulled out straight and let go, it will be drawn up again to its normal position. If the skin of one flank be tickled, the muscle beneath will contract. Pinch the same spot, or apply a drop of acetic acid, and the leg of the same side will make a sweeping movement to clear away the source of irritation; if the leg of the same side be held or cut off, the leg of the other side will repeat the movement. Place the

frog on its back, it will make no effort to regain its position. The above actions of the brainless frog are complicated, co-ordinated, purposeful in character; but however stimulated, the animal never leaps.

In the Mammal.—For some days after the division of the cord in a dog, very feeble reactions are given by the nervous mechanism of the cord. After some weeks, movements of a varied character are evoked by tickling or pinching the toes. In man, when the cord is crushed from the effects of accident or disease, the legs will start up on tickling the soles or in passing water. If the soles of a sleeping person be tickled the legs will be withdrawn.

Inhibition of Reflex Actions.—The brain exercises a powerful influence in restraining or inhibiting reflex actions. A brainless frog exhibits reflex actions better than one with brain intact. If the experiment be tried of suspending a frog with cerebral hemispheres only removed, with its toes dipping in dilute acid, and the time which elapses before their withdrawal noticed, and the same experiment repeated, stimulating the optic lobes at the same time, the time elapsing before the withdrawal will be prolonged, showing the optic lobes have inhibited the reflex centres.

Man, by an effort of will, can prevent the withdrawal of his feet if the soles are tickled.

Special Centres in the Spinal Cord.

(1) Centre for maintaining tonus of the muscles.
(2) Centre for sphincter of bladder.
(3) Centre ,, rectum.
(4) Centre of contractions of uterus.
(5) Centre for erection of genital organs.

(1.) The muscles of the body are kept in a constant state of contraction or tonus; this effect is due probably, not to an automatic, but to a reflex mechanism constantly occurring.

(2) (3.) Centres for micturition and defæcation appear to exist in the lumbar region of the spinal cord.

(4) (5.) The centres that govern the movements of the uterus and erectile tissues are situated in the lumbar region of the cord.

The above centres are to be considered reflex rather than automatic.

THE MEDULLA OBLONGATA.

The medulla is bounded above by the lower border of the pons Varolii, and is continuous below with the spinal cord at a level with the foramen magnum.

Structure.—The medulla is divided on the surface by fissures into short columns, which have received different names. Each lateral half having from before backwards :—

Anterior pyramid.
Olivary body.
Lateral tract.
Restiform body.
Posterior pyramid.

These short columns consist for the most part of white matter, and are in direct continuity with the fibres of the columns of the cord, with the exception of the olivary body. The following tables show their connection with the spinal cord and brain—

Medulla.	*Spinal cord.*
ANTERIOR PYRAMIDS . .	Anterior column of same side Lateral column of opposite side
RESTIFORM BODIES . . .	Anterior column (small part) Lateral column Posterior column
POSTERIOR PYRAMIDS . .	Posterior (median) column

Spinal cord.	*Medulla.*	*Brain.*
ANTERIOR COLUMN	1. Part of restiform body .	Cerebellum
	2. Forms fillet of olivary body	Corpora quadrigemina
	3. Anterior pyramid same side	Cerebrum
LATERAL ,,	1. Part of restiform body .	Cerebellum
	2. Anterior pyramid of opposite side	Corpus striatum
	3. Fasciculus teres	Optic thalamus
POSTERIOR ,,	1. Part of restiform body .	Cerebellum
	2. Posterior pyramid, and joins fasciculus teres .	Optic thalamus

The grey matter of the medulla is scattered through its substance, forming the numerous cen-

Functions of Medulla.

(*a*) Conductor of impulses and impressions.
(*b*) As a collection of nerve centres.

(*a*) The Medulla as a Conductor.

The **Motor** impulses travel through the anterior pyramids, decussating to the lateral column of the opposite side of the cord.

The **Sensory** path is not so well known, but not improbably it lies along the *fasciculi teretes*—small bands of white matter situated in the floor of the fourth ventricle, and formed by a continuation upwards of the lateral columns and posterior pyramids.

(*b*) Nerve-Centres in the Medulla.

(1) Respiratory centres.
(2) Vaso-motor centre.
(3) Cardiac centres.
(4) Centres for deglutition.
(5) Centre for voice.
(6) „ „ mastication.
(7) „ „ expression.
(8) „ „ salivary secretion.

(1.) The *respiratory centres* consist of an inspiratory and expiratory centre, and are both reflex and automatic. Ordinary respiration is a reflex act; a venous condition, i.e., a want of O in the blood circulating through the capillaries of the

lungs, stimulates the terminal fibres of the vagus, the vagus transmits the impression to the medulla, it is reflected along the phrenic, intercostals, &c., to the muscles of inspiration, and a fresh supply of air is drawn into the lungs. The more venous the blood the more vigorously are the terminal fibres of the vagus excited, and the more muscles brought into play. If the vagi are divided the number of respirations sink to at least one-third, but they are still continued, and the animal does not die of asphyxia. It is probable that the venous blood supplied to the medullary centre itself excites it, or like the intracardiac ganglia, it acts in an automatic manner.

(2.) The **Vaso-motor Centre** is the centre of the sympathetic system supplied to the muscular fibre of the blood-vessels, intestines, ducts, &c.

If stimulated, the vessels all over the body contract, and the arterial tension is raised; if paralysed or inhibited they dilate, and arterial tension is lowered. The vaso-motor centre keeps the blood-vessels of the body in a state of tonic contraction, it acts reflexly, and any influence which inhibits it will dilate the vessels.

(3.) **Cardiac Centres.**—The rhythmical contraction of the heart is caused by the action of its own intrinsic ganglia, but its action is regulated by ganglia situated in the medulla. There are two extra-cardiac ganglia, one *accelerating*, acting on the

heart through the sympathetic, and the other *inhibitory*, associated with the vagus.

The presence of the above ganglia render the medulla of vital importance to the living mammal. Death immediately results by destroying it. This can readily be accomplished by 'pithing,' i.e., by thrusting an awl-shaped instrument into the medulla, passing it berween the occiput and atlas, and breaking up the nervous substance.

STRUCTURE OF CORPORA QUADRIGEMINA AND CEREBELLUM.

The **Corpora Quadrigemina** are four rounded eminences, of which two, the *nates*, are in front, and two, the *testes*, are behind. They are represented in birds, reptiles, fishes, and some mammals by the optic lobes. In structure they are composed of white substance on the surface, and grey matter within. They are situated immediately above the aqueduct of Sylvius, are connected with the medulla by the fillet of the olivary body, with the cerebellum by its superior peduncles, and with the optic thalamus and optic tract by bands of white substance.

The **Cerebellum** is situated at the posterior part of the brain, and consists of peduncles, various lobes and processes. The peduncles are three in number, the superior, middle, and inferior; they serve to connect the cerebellum with the cerebrum, pons, and medulla respectively.

The cortical portion consists of grey matter, and the central portion of white substance, with a nucleus of grey, the *corpus dentatum.*

The cortical substance has three layers:

(1.) *External.*—Consists of small cells sparingly distributed, some rounded, others irregular in shape, with various processes; fibres which are for the most part processes of the large cells of the middle layer and run at right angles to the surface.

(2.) *Middle.*—Consists of cells of Purkinje arranged in a single layer. They are pyriform in shape, nucleated, and have long processes running into the external layer, and are $\frac{1}{800}$th to $\frac{1}{1000}$th inch in diameter.

(3.) *Inner* or *granule* layer.—Consists of small round granular corpuscles, about the size of white blood corpuscles, arranged in dense masses, which in stained specimens form a well-marked coloured layer.

Phenomena Exhibited after Removal of Cerebral Hemispheres.

Frog.—After the removal of the cerebral hemispheres, the animal maintains its normal attitude. If laid on its back, it will turn over and regain its feet. If its foot is pinched, it will hop away. If thrown into water, it will swim, reach the edge, clamber up and sit perfectly still. If its back is stroked it will croak. If placed in water and the

temperature raised, it will make efforts to escape. If it jump away after a stimulus has been applied, it will avoid any object in its path. It will never move without some stimulus being applied. All spontaneous action has departed. It will not feed itself, but will sit still till it decomposes.

Fish exhibit similar phenomena, they swim about in the water, but the movements are not voluntary, but result from the stimulus of the water in contact with the body.

Pigeon with cerebral hemispheres removed sits on its perch and balances itself perfectly. When thrown in the air it flies, when pinched it moves forward. If not meddled with it appears to be in a profound sleep, though occasionally it will dress its feathers or yawn. Its pupils contract normally. It resists any efforts made to open its beak, but swallows when food is placed in its mouth. It makes no spontaneous movements; the yawning and dressing itself are probably the result of the irritation of the wound.

Rabbit.—When the cerebral hemispheres are removed, the animal is at first prostrate. After a while the animal can use its legs, though the fore ones are weak. If pinched it springs forward, but, unlike frogs in a similar condition, will strike itself blindly against any obstacles in its path. When pinched severely it utters cries.

In higher animals, as cats and dogs, motor

paralysis is so marked after the removal of the hemispheres, that no conclusions concerning equilibrium and co-ordinated movements can be drawn.

At first sight it would appear that consciousness was necessary for the performance of complicated movements, and the avoidance of objects in the path; the cries elicited on pinching would appear to indicate the sensation of pain. Probably they are the result of a reflex mechanism, and are similar to walking during sleep, or the cries elicited from patients when under chloroform. The medulla contains centres for reflex actions more complicated than the cord, and the corpora quadrigemina and cerebellum contain centres for still more complex acts, as the reflex expression of emotion, the avoidance of an object when leaping, or the co-ordination of many contracting muscles.

Functions of Corpora Quadrigemina.

In man they contain (*nates or subjacent structures*)—

(1.) Centres for co-ordination of the movements of the eye-balls.

(2.) Centre for contraction of the pupils.

In some of the lower animals they contain—

(3.) Centres for co-ordination of retinal impressions with certain muscular movements.

(4.) Centre for maintenance of equilibrium.

Ferrier found on applying a weak interrupted current to the surface of the nates in the monkey, that irritation of one side caused the opposite pupil to become widely dilated, followed by dilatation of the pupil of same side. The eye-balls are directed upwards and to the opposite side, and the ears retracted. The legs become extended, the jaws retracted, and angles of mouth retracted. Irritation of the testes produces similar results, but in addition cries are elicited.

Functions of Cerebellum.

Functions.—The principal function of the cerebellum, as far as known, is the co-ordination of muscular movements in maintaining equilibrium. Every form of muscular exertion tends to overthrow the body, and disturb the balance. It is found that animals that have the largest cerebella have the most complex muscular movements. In diseases of the cerebellum, the muscles are not paralysed, there is no loss of sensation, but the movements are disorderly, and the gait awkward.

When the anterior portion of the middle lobe is injured, the animal tends to fall forwards; and backwards when the posterior part is injured. Division of the middle peduncles causes the animal to rotate on its longitudinal axis towards the injured side. Each lateral half of the cerebellum presides over the muscular movements of the same

side, the middle peduncle being connected with the motor tract of the opposite side in the pons above the decussation. It is doubtful if the cerebellum has any connection with the generative organs, as some have maintained.

Ferrier found on irritation of the upper surface of the cerebellum, movements of the eyes resulted, and also certain movements of the head and limbs.

BASAL GANGLIA.

The corpus striatum and optic thalamus are two bodies situated at the base of the brain, and projecting into the lateral ventricles.

The **Corpus Striatum** consists of two masses of grey matter: (*a*) the *intraventricular* or *caudate nucleus* projects into the lateral ventricles; (*b*) the *extraventricular* or *lenticular nucleus* is situated external and inferior, and is connected with the grey matter of the anterior perforated space and island of Reil.

The **Optic Thalamus** consists of grey matter, and is situated behind the intraventricular nucleus. These ganglia communicate superiorly with the grey matter of the surface, and inferiorly with the cord by means of the fibres of the crura, pons, and medulla.

Functions.—Destruction of one of the corpora striata causes motor *paralysis*, while stimulation causes *contraction* of the muscles of the opposite

side. An extravasation of blood into one of these ganglia gives rise to hemiplegia of the opposite side. The corpora striata are not the motor centres, but being situated on the motor tract, if injured, paralysis results. Their office in all probability is the co-ordination of muscular movements in the performance of complex actions. Each act, for instance, in learning to dance, is dependent at first upon conscious effort; after a while the movements become habitual, and are performed without any attention being required, and when the mind is otherwise engaged. Probably the corpora striata are the centres where these complex acts are rendered habitual, and automatic movements organised.

Destruction of one of the optic thalami is followed by loss of *sensation* on the opposite side, though this is denied by some. They are not the centres of sensation, though connected with the sensory path. They probably have the same relation to tactile as the corpora quadrigemina have to retinal impressions.

THE CEREBRUM.

The **Cerebral Hemispheres** form two ovoid masses of grey and white matter, with convolutions on their surface. The grey matter is mostly present on the surface, and forms a layer from $\frac{1}{4}$ to $\frac{1}{2}$ in. in depth, the amount being greatly increased by the convolutions. The white matter is arranged in

various ways, *longitudinal fibres* as the fornix, *transverse fibres* as the corpus callosum, *peduncular fibres* connecting the grey matter on the surface with the corpora striata (corona radiata), and the latter with the pons (crura).

The grey matter of the cerebrum resembles the grey matter elsewhere, though the number and shape of the nerve-cells undergo considerable variation. Five or more layers have been described, but they blend imperceptibly into one another. The most marked feature in their microscopic structure is the presence of cells resembling arrow-heads or elongated pyramids in the second and third layers, their apices being directed towards the surface. Multipolar and small round cells are present in the fourth and fifth layers.

Functions.—The grey matter on the surface is the seat of the mind, including memory, intellect, volition, the emotions. It contains centres of special sense, sight, hearing, touch, smell, taste. Special motor centres, irritation of which produces contractions of the various muscles. (Ferrier.)

According to Ferrier, the special motor and sensory centres occupy the parietal lobe or its immediate neighbourhood. By applying electrical currents to the brains of monkeys and excising certain portions, he has mapped out the various centres. He considers the frontal lobes are connected with the intellectual faculties, and the occi-

pital with the organic sensations, as hunger and thirst. Ferrier's conclusions, whilst interesting and important, have not as yet been universally accepted.

Aphasia.—The term aphasia is applied to a condition in which patients (who at the same time are for the most part suffering from right hemiplegia), have lost the faculty of speech. There is no paralysis of tongue or lips, no loss of the mental faculties, but the patient has lost the power of expressing himself in words. This condition is generally found associated with a lesion of the posterior portion of the third frontal convolution. (Broca.)

MOTOR AND SENSORY PATHS.

The path by which impulses originating in the motor centres of the cerebrum reach the muscles, and the path by which sensations reach the centres from the periphery, are not definitely settled. The following summary shows the route as far as known :—

Motor path.	Sensory path.
Grey matter of surface	Skin
Corpus striatum	Sensory nerves
[1] Crusta	Posterior roots and ganglia
Ant. pyramids	[2] Lateral columns ? (opposite side)
Lateral columns (opposite side)	Fasciculi teretes ?

[1] Crusta = superficial longitudinal fibres of pons and crura. [2] See page 202.

Anterior roots	[1] Tegmentum
Motor nerves	Optic thalamus
Muscles	Grey matter surface

FUNCTIONS OF THE CRANIAL NERVES.

First, or Olfactory.—This is the nerve of smell, and is distributed to the upper third of the mucous membrane of the nose.

Second, or Optic.—This is the nerve of sight; its fibres are acted on through the medium of the retina.

Third, or Oculo-motor.—The third nerve is purely motor, being distributed to all the muscles of the eyeball, except the superior oblique and external rectus; it also supplies the circular fibres of the iris and the ciliary muscle. Paralysis of this nerve gives rise to *ptosis*. That is, the eyelid droops in consequence of the unopposed action of the orbicularis, the eye-ball is turned outwards and downwards by the ext. rectus and sup. oblique; the pupil is dilated and fixed, and the eye cannot be accommodated to near objects. There is also double vision.

Fourth.—Is purely motor, and supplies the superior oblique.

Fifth, or Trifacial.—(a) *Ophthalmic* or *first division* is purely sensory to the eye and forehead;

[1] Tegmentum = deep longitudinal fibres of pons and crura.

injury to this nerve causes ulceration and sloughing of the cornea. (b) *Superior Maxillary* or *second division*, is purely sensory to skin of face, mucous membrane of the nose, and teeth of upper jaw. Pungent odours, as of ammonia, are perceived through this nerve. (c) *Inferior*, or *third division*, is sensory to the tongue, mouth, teeth, and skin covering lower jaw. It confers tactile sensibility on the tongue, and through it pungent and acid tastes, as of pepper, vinegar, and mustard, are perceived. Motor filaments are supplied to the muscles of mastication, including the buccinator, anterior belly of digastric, and mylo-hyoid.

Sixth.—This nerve is motor to the external rectus.

Seventh.—Includes the facial and auditory. The *facial* is motor and supplies the muscles of the face, lips, stylo-hyoid, digastric, soft palate (through the spheno-palatine ganglion), and external muscles of the ear. It is the special muscle of expression : when injured the corresponding side of the face becomes a blank, the mouth is oblique and dragged towards the sound side. The eye is wide open and cannot be closed ; food accumulates between the gum and cheek, and the pronunciation of labial consonants is difficult. It gives off the chorda tympani, the latter giving a small branch to the stapedius, and is distributed to the tongue and submaxillary glands. The chorda tympani probably

only influences taste through the medium of the salivary glands. The *auditory* is the special nerve of hearing.

The **Glosso-pharyngeal.**—This nerve is motor to the stylo-pharyngeus and constrictors. It is supplied to the circumvallate papillæ, and is the special nerve of taste to the posterior surface of the tongue. It specially discriminates bitters and savoury foods.

The **Vagus,** or **Pneumogastric.**—This nerve arises from the medulla, immediately below the glosso-pharyngeal. It contains both sensory and motor fibres, though part of the latter are derived from the spinal accessory. The vagus is distributed to three different sets of organs—(a) the lungs and respiratory passages; (b) the heart; (c) the pharynx, œsophagus, and stomach.

(a) The *superior laryngeal* is the nerve of sensation to the mucous membrane of the larynx, and supplies one muscle—the crico-thyroid. Paralysis of this nerve causes loss of sensation in the larynx, and interferes with the utterance of high notes from paralysis of the crico-thyroid. The *inferior laryngeal* is the motor nerve to the intrinsic muscles of the larynx, except the crico-thyroid. Stimulation of the central end of the superior laryngeal causes a flaccid state of the diaphragm, and excites contractions of the expiratory muscles. The vagus supplies several different sets of fibres to the lungs, motor to

the muscular fibre of the bronchi, ordinary sensory fibres, and fibres which, when stimulated, excite the contraction of the inspiratory muscles.

(b) The vagus contains fibres which inhibit the action of the heart, by antagonising the activity of the intracardiac ganglia. Also sensory fibres which convey the sensations of pain, as in angina pectoris.

(c) The vagus supplies motor and sensory fibres to the soft palate, pharynx, œsophagus, and stomach. Stimulation of the central end of the cut vagus causes a reddening of the mucous membrane of the stomach. The vagus contains fibres which inhibit the vaso-motor centre, dilate the blood-vessels of the stomach, and cause the gastric juice to be poured out.

Effects of dividing the Vagi.—If the vagi be divided in the neck of a rabbit or dog, the following phenomena will be noticed :—

(1.) The number of respirations per minute will fall to one-third their normal number, but each respiration is about five times as deep, so that the quantity of air entering the chest is not altered. The vocal cords are apt to fall together from paralysis of the muscles of the larynx. Foreign bodies, as food ingested and mucus, are liable to accumulate in the air passages.

(2.) The number of the contractions of the heart will be increased about 20 per cent., and in the dog at least there is increased arterial pressure.

(3.) Food, if swallowed, accumulates in the œsophagus Presence of food in the stomach no longer excites the secretion of gastric juice; though this latter effect is denied by some.

(4.) The rabbit dies in 24 hours, the dog in a few days, death taking place from accumulation of mucus or foreign bodies in the lungs and air-passages, often giving rise to pneumonia.

Spinal Accessory.—This is purely a motor nerve, though it receives some sensory branches from the vagus. Its motor branches are distributed to the trapezius and sterno-mastoid, and supply the vagus with motor nerves for the pharynx and larynx.

Hypoglossal, or **Ninth.**—This nerve is purely motor, being distributed to hyo-glossus, genio-hyoid, genio-hyo-glossus, thyro-hyoid, and muscles of the tongue, and by its descending branch to the omo-hyoid, sterno-hyoid, and sterno-thyroid.

THE SYMPATHETIC SYSTEM.

The sympathetic system consists of numerous ganglia and nerves, which supply the viscera, glands, and blood-vessels of the body. The nerves consist both of medullated and non-medullated nerve tubules, the latter greatly predominate. The sympathetic nerves are closely connected, and freely intermix with the cerebro-spinal nerves. There are numerous ganglia belonging to the sympathetic

system, and the nerves very frequently form plexuses, which for the most part surround blood-vessels, and are conducted by them to the viscera.

The **Cephalic** portion of the sympathetic consists of four ganglia: 1. Ophthalmic. 2. Spheno-palatine, or Meckel's ganglion. 3. Otic, or Arnold's. 4. Submaxillary ganglion.

The **Cervical** portion consists of three ganglia on each side of the neck, the superior, middle and inferior. The *superior ganglion* is the largest of the three; it gives off several branches. Its superior branch is the direct continuation upwards of the ganglion; it accompanies the internal carotid into the skull, and divides into an outer and inner branch. The *outer* branch forms the *carotid plexus*, which lies on the outer side of the internal carotid, and communicates with the Gasserian and Meckel's ganglia and the sixth nerve. The *inner branch* also accompanies the internal carotid, and forms the *cavernous plexus*; it communicates through the plexus with the third, fourth, fifth, and sixth nerves, and with the ophthalmic ganglion. Terminal filaments from these two plexuses accompany the branches of the internal carotid. The superior cervical ganglion also gives an *inferior* branch to the middle ganglion, *external* branches to cranial and spinal nerves, *internal* branches to pharynx, larynx, and heart (the latter being called the superior cardiac nerve), and *anterior* branches to the

external carotid. The *middle cervical ganglion* communicates with the ganglia above and below, and gives spinal, thyroid, and cardiac branches. The *inferior cervical ganglion* communicates with the middle ganglion, gives branches which travel with the vertebral artery and form a plexus around it, also the inferior cardiac nerve.

Cardiac Nerves.—The superior, middle, and inferior cardiac nerves, come from the cervical ganglia; the middle is the largest. The *deep cardiac plexus* lies on the bifurcation of the trachea and behind the arch of the aorta, and is formed by the cardiac branches of the sympathetic and vagi. The *superficial cardiac* plexus lies below the arch of the aorta and in front of the right pulmonary artery; it helps to form the *anterior coronary* plexus. The *posterior coronary plexus* being formed by the deep cardiac plexus.

The **Thoracic Sympathetic** consists of a series of ganglia, placed on each side of the spine, resting against the heads of the ribs. The *external* branches of the ganglia communicate with the dorsal spinal nerves. The *internal* branches of the upper six supply the aorta and pulmonary plexus; the internal branches of the lower six unite to form the three splanchnic nerves. The *great splanchnic* is formed by branches from 6th to 10th, it perforates the diaphragm, and terminates in the semi-lunar ganglion and renal plexus. The lesser splanchnic is formed

by 10th and 11th ganglia, pierces the diaphragm, and enters the cæliac plexus. The smallest splanchnic comes from the last ganglion and passes to the renal plexus. The solar, or epigastric plexus, surrounds the cæliac axis, and sends branches forming plexuses, which surround the phrenic, gastric, hepatic, splenic, renal, superior and inferior mesenteric and spermatic arteries. The semi-lunar ganglia, which are situated on each side of the cæliac axis, are the largest ganglia of the body.

The **Lumbar portion** of the sympathetic consists of four ganglia connected by nerves.

The **Pelvic Sympathetic** consists of four or five ganglia on each side. The *hypogastric plexus* is situated between the common iliacs, and supplies branches through the inferior hypogastric plexus to the rectum, bladder prostate, vagina and uterus. Branches accompany the external iliacs to the lower extremities.

Functions of the Sympathetic.—The centre of the sympathetic system is in the medulla; section of the cord below the medulla causes a general dilatation of blood-vessels throughout the body. The ganglia take part in the reflex and automatic acts of the body; such are the ganglia of the intestines and the ganglia situated in the heart. The non-striated muscles of the body, as the muscular fibres surrounding the blood-vessels, are supplied by the sympathetic.

The **Cervical Sympathetic** contains—

1. Vaso-motor fibres for the corresponding side of the head.
2. Fibres which supply the dilating muscular fibres of the iris.
3. Accelerating fibres for the heart.
4. Fibres for the salivary and lachrymal glands.
5. Fibres proceeding to the medulla which excite the inhibitory fibres of the vagus.
6. Fibres to medulla, which stimulate the vaso-motor centre.

The **Thoracic Sympathetic** gives off through the splanchnics—

1. Vaso-motor fibres for the vessels of the viscera.
2. Inhibitory fibres for intestine.
3. Fibres inhibiting renal secretion.
4. Fibres which inhibit the heart reflexly.

The **Abdominal** and **Pelvic Sympathetic** contain fibres which are distributed to the vessels of this part, but little is known of them experimentally.

SECTION XV.

THE SENSES.

SMELL.

THE mucous membrane of the nose is supplied with branches of the olfactory nerve in the upper third of the nasal cavity; branches of the second division of the fifth are distributed over the whole surface. The surface is increased by the turbinated bones, which are highly developed in some of the lower animals. The mucous membrane of the upper or olfactory region is provided with modified columnar cells, with which the terminations of the olfactory nerves are connected.

Odoriferous substances give off minute particles, which, when inhaled, come in contact with the epithelium of the olfactory tract, and excite the terminations of the olfactory nerve, giving rise to the sensations of smell. Oxygen seems necessary to the development of the sense of smell.

Pungent odours, as of ammonia, are perceived by the fifth.

TASTE.

The tongue is the organ of taste. The mucous membrane of the tongue receives the impressions made upon it by the food, and these impressions are carried to the brain by special nerves. The papillæ lodge the terminations of the nerves and the *taste-buds* with which the nerves are connected. The nerves which, directly or indirectly, administer to the sense of taste are the (1) glosso-pharyngeal supplied to the circumvallate papillæ, (2) lingual, to the front and sides of the tongue, and (3) chorda tympani.

	Special function
1. Glosso-pharyngeal	bitter tastes. savoury tastes.
2. Lingual	pungent tastes, acids, pepper, &c. sweet tastes. common sensation.
3. Chorda tympani .	stimulates secretion of saliva.

It is necessary for the development of taste, that the substance should be in solution, one of the offices of the saliva being to dissolve sapid substances and so render them more evident to the taste.

FEELING AND TACTILE IMPRESSIONS.

The skin contains special organs as *end-bulbs*, *touch-corpuscles*, and also the termination of nerves, which, when stimulated by contact, excite the sensations of touch. The afferent nerves are distributed

to all parts of the surface of the body, and convey to the brain the sensations excited by contact. Sensations of touch may be divided into—

(*a*) Sensations of pain.
(*b*) Sensations of temperature.
(*c*) Sensations of pressure.
(*d*) Tactile judgments.
(*e*) Muscular sense.

It is probable there are separate nerves for conveying to the brain the different sensations of pain, temperature, &c. There is reason to believe that in the spinal cord, at least, the purely tactile sensations travel along special strands of nerves.

SIGHT.

THE EYE.

Structure.—The EYE has three tunics, or layers.

(1) Sclerotic and cornea.
(2) Choroid, iris, and ciliary processes.
(3) Retina.

And three refracting media.

(4) Aqueous humour.
(5) Crystalline lens.
(6) Vitreous humour.

(1.) The **Sclerotic** is a firm, dense, fibrous membrane, forming $\frac{5}{6}$ths of the external coat of the eyeball. It is composed of white fibrous tissue, and

fine elastic fibres, with numerous connective-tissue corpuscles. It is continuous in front with the cornea, and is pierced behind by the optic nerve. It contains blood-vessels, but no nerves.

The **Cornea** is transparent, and forms $\frac{1}{6}$th part of the external tunic. It has five layers.

(1) Epithelial cells of conjunctiva.
(2) Anterior elastic lamina.
(3) Cornea proper.
(4) Posterior elastic lamina.
(5) Layer of flattened cells lining anterior chamber.

The cornea proper is continuous with the sclerotic, and consists of about sixty lamellæ of transparent fibrous tissue, and numerous corpuscles contained in the cell-spaces. It is evascular, but contains nerves.

(2.) The **Choroid** is a dark membrane lining $\frac{5}{6}$ths of the eyeball, internal to the sclerotic. Its external layer consists of veins—the *venæ vorticosæ*. Its middle layer consists of fine capillaries, and is called the *tunica Ruychiana*. The internal layer is formed of hexagonal cells, loaded with dark pigment granules.

The **Ciliary Processes** are formed by the plaiting and folding inwards of the middle and internal layers of the choroid; they are attached to the suspensory ligament in front, and are arranged in a circle around the lens.

The **Iris** is a circular contractile diaphragm in front of and touching the anterior surface of the lens. It is attached by its circumference to the cornea, sclerotic, and choroid, at their junction with one another. Its inner edge forms the pupil. In structure it consists of muscular fibres, a fibrous stroma, and pigment cells. The circular muscular fibres surround the pupil, the radiating fibres pass from the pupil to the circumference. *Arteries*, long and anterior ciliary. *Nerves*, radiating fibres, sympathetic; circular, third nerve.

The **Ciliary Muscle** consists of involuntary muscular fibres; it arises at the junction of the cornea and sclerotic, and is inserted into the choroid. When it contracts it pulls forward the ciliary processes and choroid, and relaxes the suspensory ligament. It is supplied by the third nerve.

(3.) The **Retina** forms the inner tunic of the eye, and contains the terminations of the optic nerve and certain minute bodies, the *rods* and *cones*, with which the optic nerve is connected. Its thickness varies from $\frac{1}{50}$ to $\frac{1}{200}$ in., it is thicker behind than in front, and contains eight layers, which from before backwards are—

(1) Nerve fibres.	(5) Outer molecular.
(2) Nerve cells.	(6) Outer nuclear.
(3) Inner molecular.	(7) Rods and cones.
(4) Inner nuclear.	(8) Pigment cells.

The optic nerve passes through the retina and spreads out on its surface. External to this layer are the nerve cells: they are of pyriform shape and have numerous branches. The *rods* are of elongated form, the *cones* are shorter and thicker at their bases, the base being directed towards the lens. The fibres of Müller pass directly through the layers and help to bind them together.

The **Macula Lutea.**—In the centre of the retina, and corresponding to the axis of the eye, is a yellow spot—the macula lutea; it contains some yellow pigment, and is about $\frac{1}{20}$ in. in diameter. In its centre is a minute depression, the *fovea centralis.* The rods are absent over the yellow spot, and the cones longer and narrower than elsewhere. The other layers are very thin over the fovea centralis.

The **Porus Opticus,** or **Optic Disc.**—The optic nerve enters the retina about $\frac{1}{10}$ in. on the inner side of the yellow spot. It appears as a round white disc, and is called the porus opticus. The *arteria centralis retinæ* enters through its centre. The rods and cones are not present over the porus opticus.

(4.) The **Aqueous Humour.**—The aqueous fluid fills the space between the lens and cornea. It closely resembles water, but contains a small quantity of salts dissolved in it.

(5.) The **Lens** is about $\frac{1}{3}$ in. in diameter, bi-convex, being more convex behind than in front, and is

surrounded by a capsule. The outer portion of the lens is soft and easily detached, the succeeding layers are firmer, and the central part or nucleus is harder still. Faint white lines may be seen radiating from the centre to the circumference, which in the fœtus are three in number and well-marked. In the hardened lens, a succession of concentric laminæ may be detached, like the coats of an onion. The laminæ are composed of fibres, their edges are finely serrated and fit into each other. The fibres are six-sided prisms, and are in reality elongated cells, and in the young state contain nuclei.

Changes in the Lens by Age.—In the *fœtus* the lens is nearly spherical. In the *adult* the anterior surface becomes more flattened than the posterior. In *old age* it becomes more flattened at both surfaces, and its transparency is impaired.

(6.) The **Vitreous Humour.**—The vitreous body occupies the chamber between the lens and retina. It is of a gelatinous consistence, and forms a support for the retina. When hardened it exhibits a laminated structure and numerous corpuscles scattered through it.

ACCOMMODATION.

If a convex lens be made to throw the image of an object upon a screen, and then the object move farther away or nearer to the lens, the image on the screen will be indistinct, being out of focus, and the

lens must be moved to get a distinct image. In a similar manner, the crystalline lens must be moved or its convexity altered when viewing objects at different distances, in order to obtain distinct images on the retina. If distant objects are being looked at, objects a foot distant will be indistinct, and *vice versâ*, unless some accommodating mechanism exists. This is accomplished, not by moving the lens as in a telescope, but by altering its convexity. The lens is more or less elastic, and its anterior surface is kept flattened by the tension of the elastic suspensory ligament. If the suspensory ligament is relaxed the lens becomes more convex, and when the suspensory ligament tightens it flattens the lens again. The contraction of the ciliary muscle, by drawing forward the ciliary processes, relaxes the suspensory ligament, and therefore the lens becomes more convex.

The accommodation of the eye for near objects is a muscular act, being effected by the contraction of the ciliary muscle, the lens becoming more convex; accommodation for distant objects is simply effected by the elasticity of the suspensory ligament, the ciliary muscle relaxing and the lens becoming flatter. Images of distant objects are thrown upon the retina when the ciliary muscle is not contracting, images of near objects are thrown behind, and the lens must be rendered more convex in order to bring them to a focus on the retina.

Hypermetropia.—In the hypermetropic eye, the horizontal axis of the eye is shortened, so that the retina is nearer the lens than in the normal eye. The images of objects are formed behind the retina, those of distant objects can be brought to focus on the retina by contraction of the ciliary muscle, but the images of near objects are formed so far behind that no effort of the ciliary muscle will focus them on the retina. Convex spectacles are used especially for near objects.

Myopia.—In the myopic eye, the horizontal axis is elongated, so that the retina is farther away from the lens than in the normal eye. The image of objects will fall in front of the retina, especially the images of distant objects. The lens cannot be rendered sufficiently flat to bring them into focus, and concave glasses must be used.

Presbyopia, or the long sight of old people, consists in a defective condition of the accommodation apparatus, so that while seeing distant objects distinctly, near ones are indistinct.

Astigmatism.—It sometimes happens that the surfaces of the cornea are not equally convex, the cornea being more convex in the vertical meridian than in the horizontal, or *vice versâ*. This will interfere with the distinctness of vision; most eyes are slightly astigmatic, with the greater curvature in the vertical meridian.

Movements of the Pupil.

The contraction of the pupil, when light falls on the eye, is a reflex act. The dilating fibres are supplied by the sympathetic, and the circular by the third. The sympathetic is constantly in action, so that when the stimulus of light is removed the pupil dilates.

The circular fibres contract and overcome the contraction of the radiating when stimulated by light or during sleep. Division of the sympathetic in the neck of the rabbit causes contraction of the pupil.

The pupil *contracts*—

(1) *When stimulated by light.*

(2) *When we accommodate for near objects.*

(3) *When the eyeball is turned inwards.*

(4) *Through the action of certain drugs—opium, calabar bean.*

The pupil *dilates*—

(1) *When the stimulus of light is removed.*

(2) *When the eye accommodates for distant objects.*

(3) *Through the action of certain drugs, as atropine.*

(4) *In dyspnœa.*

Functions of the Retina.

The retina receives the images of objects, and through its agency they are perceived by the mind

The exact use of the different layers of the retina is unknown, but the perception of light is probably due to the rods and cones. The power of distinguishing colour is said to be due to the cones.

The *optic nerve* enters the retina $\frac{1}{10}$ in. to the inner side of the yellow spot, and when viewed from the front by means of an ophthalmoscope, it appears like a round white spot termed the optic disc. The optic disc is insensible to light. This can be demonstrated by fixing the right eye (the left being closed) on a dark spot on a sheet of paper held 10 in. from the eye. If a black point, like the tip of a pen, be made to move from right to left towards this spot, it becomes invisible when it reaches a point $2\frac{1}{2}$ in. from it, but will reappear again on moving nearer. The image of the spot is projected on to the macula lutea in the centre of the retina, and the image of the moving point falls on the optic disc ($\frac{1}{10}$ in. from yellow spot) when $2\frac{1}{2}$ in. from the fixed black spot. This shows that the optic disc is insensible to light.

The *macula lutea* occupies the centre of the retina, and is the most sensitive part of it. Small objects appear most distinct when their images fall in the centre of the retina, as when we look straight at an object. Points which appear separate when their images fall on the yellow spot, appear as only one when their image falls elsewhere, as when they are moved out of the centre of the field.

Purkinje's Figures.—If a strong ray of light be concentrated on the edge of the sclerotic near the cornea, the light will pass through the sclerotic and throw the shadow of the retinal vessels on the retina, a dark branching figure being seen. Or, if on entering a dark room, a candle is moved up and down by the side of the eye, the same appearance will be seen. As the vessels lie in front of the rods and cones, it is probable that it is through them that light is perceived.

HEARING.

THE EAR.

The organ of hearing is divided into—

(1) External ear.
(2) Middle ear or tympanum.
(3) Internal ear or labyrinth.

(1.) The **External** ear consists of the pinna and the external auditory canal. The pinna consists of an irregularly concave piece of yellow elastic cartilage, which receives the sound and conducts it to the meatus. The external auditory canal is $1\frac{1}{4}$ in. in length, partly cartilaginous and partly bony, and conveys the vibrations of sound to the membrana tympani, which closes its inner end.

(2.) The **Tympanum** is a small cavity hollowed out of the temporal bone, which communicates with

the external air through the Eustachian tube, and contains a chain of bones which convey vibrations received by the membrana tympani to the fluids surrounding the nervous mechanism of the internal ear. Its *roof* is formed by a thin plate of bone which separates it from the cranial cavity. The *floor* is narrow, and corresponds to the jugular fossa beneath. Its anterior wall corresponds with the carotid canal, and presents the canal for the tensor tympani and the opening of the Eustachian tube. The *posterior wall* presents the openings of the mastoid cells. The *outer wall* is occupied by the membrana tympani, and near its margin are three small apertures, the *iter chordæ posterius* and *iter chordæ anterius* for the entrance and exit of chorda tympani, and the *Glasserian fissure* for the handle of the malleus, laxator tympani and some tympanic vessels. The *membrana tympani* is a thin transparent membrane which forms the outer wall of the tympanic cavity; it is of oval form, and placed obliquely, so that its outer surface looks downwards and somewhat forwards. The handle of the malleus is attached to its inner surface, and draws the membrane inwards, so that its outer surface is concave.

The *inner wall* presents the—

1. Fenestra ovalis.
2. Fenestra rotunda.
3. Promontory.

4. Ridge of the aquæductus Fallopii.
5. Pyramid.
6. Opening for the Stapedius.

The *fenestra ovalis* communicates with the vestibule, and is closed by a membrane to which the base of the stapes is attached. The *fenestra rotunda*, placed below and behind, opens into the cochlea, but is closed by a membrane in the recent state. The *promontory* corresponds with the first turn of the cochlea. The *pyramid* is a conical projection which transmits the *stapedius muscle* through the minute canal in its centre.

The *ossicles of the tympanum* consist of the malleus, incus, and stapes.

The *malleus* consists of a head, a neck, and three processes. The *incus* resembles a bicuspid tooth and consists of a body and two processes. The *stapes* resembles a stirrup. The muscles of the tympanum are the *tensor tympani*, which arises from the petrous portion of the temporal bone and the walls of its canal; it is reflected round the processus cochleariformis, and is inserted into the root of the handle of the malleus. The *laxator tympani* arises from the spine of the sphenoid, passes through the Glasserian fissure, and is inserted into the neck of the malleus. This muscle is considered by some to be a ligament. The *stapedius* arises from the walls of its canal, and is inserted into the neck of the stapes.

(3.) The **Internal Ear** or **Labyrinth** consists of the vestibule, semicircular canals, and cochlea.

The **Vestibule** is situated on the inner side of the tympanum, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoid in shape, and measures about $\frac{1}{5}$ in. in length. On its *outer* wall is the fenestra ovalis, closed by the base of the stapes and membrane; on its *inner* wall is the *fovea hemispherica*, pierced by minute holes; for the filaments of the auditory nerve and opening of the aquæductus vestibuli; on its *roof* is a small depression, the *fovea semi-elliptica*, and *behind* are the five openings of the semicircular canals, and in *front* an opening which communicates with the cochlea.

The **Semicircular Canals** are three bony canals of about $\frac{1}{20}$th in. in breadth, which open into the vestibule, on its posterior aspect, by five openings, the superior and posterior having one opening in common.

The *superior* is vertical and transverse in position.

The *posterior* is vertical and longitudinal.

The *external* is horizontal.

The **Cochlea** is situated in front of the vestibule and resembles a small snail-shell. It is $\frac{1}{4}$ in. in length, and consists of a canal which winds spirally around a central column. This osseous canal is $1\frac{1}{2}$ in. in length, and winds $2\frac{1}{2}$ times round the central

axis or modiolus. The canal is divided into two by a delicate plate of bone, the lamina spiralis, which follows its windings. From the edge of the lamina spiralis two membranous structures stretch to the outer wall, dividing it into three canals. The membranes are called the *m. of Reissner* and the *m. of Corti*, or *membrana basilaris.* The canals are the *scala vestibuli*, *scala tympani*, and *scalia media* or *canal of Corti*, the latter interposed between the other two. The scala media contains the organ of Corti. The scala tympani communicates with the tympanum by means of the foramen rotundum, the scala vestibuli with the vestibule, though both openings are closed by a membrane in the recent state.

The *membranous labyrinth* is a closed membranous sac containing fluid. It corresponds in shape to the vestibule and semicircular canals, and is continuous with the canal of Corti; it contains the terminations of the auditory nerve, is filled with the endolymph and surrounded by the perilymph. The vestibular portion consists of two sacs, the *utricle*, lodged in the fovea hemi-elliptica, and the *saccule* in the fovea hemispherica. The membranous semicircular canals are about $\frac{1}{3}$rd the diameter of the osseous canals; they are hollow, and open into the utricle. In the endolymph of the utricle, saccule, and ampullæ of the semicircular canals there are hair-like processes attached to the epithelial cells,

and numerous crystals of carbonate of lime called *ooliths.*

The *membranous cochlea* consists of the S. vestibuli and S. tympani, containing perilymph, and the canal of Corti, containing the endolymph and organ of Corti.

The *organ of Corti* is situated on the membrana basilaris, and consists of the rods of Corti, and numerous hair-cells. The rods of Corti are arranged in rows, their upper ends in contact with one another, and their lower ends resting on the membrana basilaris. The hair-cells are supported on the rods, and consist of columnar epithelium provided with hair-like processes.

The **Auditory Nerve** is distributed to the vestibule and cochlea. The vestibular division divides into five branches, which are distributed to the utricle, the saccule, and the three ampullæ of the semicircular canals. The terminations of the nerves are connected with the hair-cells, and float in the endolymph. The cochlea division passes into a small bony canal, which runs up the modiolus, and then is distributed to the rods of Corti, and hair-cells passing between the layers of the lamina spiralis.

Functions of the External and Internal Ear.—The *external ear* collects the waves of sound, and the auditory canal conveys them to the membrana tympani.

The *membrana tympani* receives the waves, and is set into vibrations accordingly.

The *tensor tympani* renders tense the membrana tympani. When the membrane is tense it readily responds to high sounds, and when relaxed it is best adapted for receiving low sounds.

The *auditory ossicles.*—The malleus is attached by its handle to the membr. tymp. and any movement of the latter is communicated to the malleus. The incus and stapes transmit the vibrations to the membrane covering the fenestra ovalis, and the vibrating membrane sets in motion the perilymph of the vestibule.

The *stapedius* regulates the action of the stapes.

The *Eustachian* tube forms a communication between the tympanum and external air, and is opened during the act of swallowing.

The *labyrinth.*—The vibrations communicated by the ossicles to the perilymph of the vestibule pass through the cochlea, ascending by the scala vestibuli, and descending by the scala tympani to the fenestra rotunda; and also passing along the perilymph of the semicircular canals. The vibrations of the perilymph are communicated to the endolymph of the scala media, and the terminations of the auditory nerve by means of the rods of Corti and hair-cells. The endolymph contained in the membranous labyrinth of the vestibule and semicircular canals in like manner communicates the

vibrations to the auditory nerve through the medium of the hair-cells.

The vibrations travel along the following channels to reach the auditory nerve—

Concha.
External auditory meatus.
Membrana tympani.
Ossicles.

Perilymph of vestibule—utricle and saccule.

Perilymph of S. vestibuli	Perilymph of semicircular canals
„ S. tympani	Endolymph of ampullæ
Endolymph of C. of Corti	Ooliths and hair-cells
Basilar membrane	
Rods of Corti	Auditory nerve
Hair-cells	
Auditory nerve	

SECTION XVI.

MECHANISM OF SPEECH.

SPEECH constitutes one of the great differences between man and the lower animals, and is of great importance as a means of communication between man and his fellows. It depends—

1. Upon a suitable mechanical apparatus for the production of sounds.

2. Other mechanical arrangements in the oral cavity for modifying those sounds.

3. Nervous centres for co-ordinating the muscular movements, and intellectual powers of a high order to express ideas in language.

I. THE LARYNX.

The *larynx* consists of cartilages, various muscles and ligaments.

1. The **Cricoid**—resembles a signet ring, being deep behind and narrow in front. It gives attachment at its front and sides to the crico-thyroid, and behind this to the inferior constrictor. Posteriorly it gives attachment to the œsophagus and

crico-arytenoides posticus. Its upper border gives attachment to the crico-thyroid membrane and crico-arytenoideus lateralis. It has articular surfaces, for the thyroid behind, and arytenoids superiorly.

2. The **Thyroid** consists of two lateral halves, of a quadrilateral shape, joining at an acute angle in front, and forming at their upper angle the *pomum Adami*. The outer surface gives attachment to the thyro-hyoid, sterno-thyroid, and inferior constrictor. At the posterior inferior angle there are two cornua for articulation with the cricoid. Its posterior border gives attachment to the stylo-pharyngeus. At the angle formed by the alæ on the inner aspect it gives attachment to the epiglottis, the false and true vocal cords, and thyro-arytenoidei. Its inferior border gives attachment to the crico-thyroid.

3. The **Arytenoid** cartilages resemble pyramids, having three surfaces, a base, and apex. The base is seated on the cricoid, its anterior angle giving attachment to the true vocal cords, and its external angle to the crico-arytenoid, posticus and lateralis. The posterior surface gives attachment to the arytenoids, and the anterior to the false vocal cords, and thyro-arytenoids.

4. The **Epiglottis** is shaped like an obovate leaf, being round at its free extremity, and pointed inferiorly where it is attached to the angle formed by the alæ of the thyroid.

It is composed of yellow elastic cartilage, and covers the superior opening of the larynx, and is covered by mucous membrane, which is reflected to the neighbouring parts.

5. The **Cornicula Laryngis,** or **Cartilages of Santorini,** are two small nodules of yellow fibro-cartilage, which are placed at the summit of the arytenoids.

6. The **Cuneiform Cartilages,** or **Cartilages of Wrisberg,** are two yellowish cartilaginous bodies situated in the aryteno-epiglottidean folds.

Structure of the cartilages.—The epiglottis, cornicula laryngis, and cuneiform cartilages, consist of yellow fibro-cartilage. The other cartilages are hyaline, resembling the costal, and are prone to ossify.

The **Vocal Cords**—so called from their being concerned in the production of the voice—are two bands of yellow elastic tissue covered with mucous membrane, attached in front to the angle between the alæ of the thyroid, and behind, to the anterior angle of the base of the arytenoid. They are continuous below with the crico-thyroid membrane, and their free edges are directed upwards.

The **False Vocal Cords** are two folds of mucous membrane, enclosing fibrous tissue, situated above the true vocal cords.

The **Ventricle of the Larynx** is a fossa between the true and false vocal cords: it communicates with

the sacculus laryngis, and forms a pouch between the superior or false vocal cords and the thyroid cartilage.

The **Rima Glottidis** is the narrow fissure between the inferior or true vocal cords. In the male it measures eleven lines, and its breadth is from three lines to half an inch. In the female and in the male below puberty it is eight lines in length, and two lines in breadth. When a sound is produced its edges are approximated.

Action of the Muscles.—The *crico-thyroids* tighten the vocal cords by pulling the anterior part of the thyroid downwards. The *thyro-arytenoids* have an opposite effect. The *crico-arytenoid, laterales*, by pulling forward the outer angle of the arytenoid cartilages, will approximate the vocal cords. The *posterior crico-arytenoids* pull back the outer angle of the arytenoid cartilages, and separate the vocal cords.

The *arytenoids*, by pulling the arytenoids nearer together, approximate the vocal cords.

Different Characters of Voice.

1. **Loudness** or **Intensity** depends upon the amplitude of the movements of the cords, and hence upon the force of the expiratory blast.

2. **Pitch** depends upon the rate of the vibrations. The number of vibrations being dependent upon the tension and length of the cords. The tenser the

cords the higher the pitch, the shorter the cords the higher the pitch. When a high note is being made the cords are approximated, when a low note they are separated. It is said that no sound is elicited if they are separated more than one-tenth or one-twelfth of an inch. Males have longer cords than females and children, and hence have a lower range of notes. But every voice has a certain range, in consequence of the power possessed by each individual to vary the tension of the cords. The following table will exhibit the action of the muscles in altering the pitch :

Govern Pitch of the Voice.

Raise pitch	crico-thyroids, sterno-thyroids	depress front of thyroid and stretch v.cd's
	crico-arytenoid lat., arytenoidei	approximate v.cd's
Lower pitch	thyro-arytenoids, thyro-hyoids	elevate thyroid and relax v.cd's.
	crico-ary. post.	open glottis

3. **Quality** of the voice depends chiefly upon individual peculiarities.

Nerve-supply.—The chief muscle which makes tense the vocal cords, the crico-thyroid, is supplied by the superior laryngeal, the rest of the intrinsic muscles by the recurrent laryngeal.

Movements during Respiration.—During in-

spiration the rima glottidis opens widely, and is in a semi-contracted state during expiration.

It is closed entirely prior to a cough or sneeze.

The Larynx as a Musical Instrument.—The different kinds of musical instruments are strings, flutes, and reeds. In certain instruments, as the harp, the musical sounds are produced by vibrating *strings*, but no strings, as short as the vocal cords, could give a tone comparable to the human voice. In the *flute-pipes* the sound is produced by the vibration of an elastic column of air. Possibly, this is the case with the notes of birds, but it would require a column of six feet to produce the ordinary bass voice. In the *reeds* the sound is produced by the vibrations of certain tongues, as in the accordion, harmonium, &c. With this kind of instrument the human larynx agrees, the notes being produced by the vibrations of the vocal cords, the pitch depending on their length and tension.

II. ARTICULATE SOUNDS.

The larynx produces tones only, but speech consists in the modification of the laryngeal tones, so as to produce articulate sounds.

Vocal Sounds.—The only true vocal sounds are the *vowels*: the *consonants* are sounds produced, not by the vocal cords, but by the expiratory blast being modified in the mouth and throat.

The vowel sounds are produced in the larynx,

but are modified in their passage through the pharynx and mouth. Thus in pronouncing the vowel *oo* the lips are protruded, and the larynx is depressed, making the column of air as long as possible. With the sound *ee* the lips are retracted, and the larynx raised, making the column of air as short as possible.

Consonants are sounds produced in the buccal cavity. The *labials* are produced by approximation of the lips. The *dentals* by the approximation of the tongue to the teeth or hard palate. The *gutturals* by the approximation of the root of the tongue to the soft palate. Other varieties, as *explosives*, *aspirates*, and *resonants*, are formed by a rush of air through the lips, or teeth, or causing the nasal chamber to act as a resounding cavity.

SECTION XVII.

ORGANS OF GENERATION.

UTERUS.

The **Uterus** is a hollow, muscular, pear-shaped organ, with thick walls, situated in the pelvic cavity. It is flattened from before backwards, about 3 in. long, and 7 to 12 drs. in weight. It consists of a fundus, a body, and cervix. The *fundus* is rounded, and is directed upwards and forwards. The *cervix* projects into the vagina, and opens into it by means of a transverse fissure, the os uteri. The *cavity* is of triangular shape in its upper part, the base being towards the fundus, where the Fallopian tubes enter; the inferior angle is constricted and forms the internal os, which opens into the cavity of the cervix. The cavity of the cervix is somewhat spindle-shaped, being constricted at the internal and external orifices.

Structure.—The uterus consists of serous, muscular, and mucous coats. The *serous* layer passes from the rectum on to the upper part of the vagina,

then upwards, covering the whole of the posterior wall of the uterus; it is reflected over the fundus and covers only three-fourths of the anterior surface and passes on to the bladder. Two folds, which connect the sides of the uterus with the walls of the pelvis, form the broad ligaments, and contain the Fallopian tubes and ovaries.

The *muscular* coat consists of external, middle, and internal layers, of which the latter is the thickest: it forms concentric rings round the entrance of the Fallopian tubes and round the cervix.

The *mucous membrane* lining the cavity of the uterus is smooth and soft, and of a dull red colour, and contains numerous tubular glands.

The membrane of the cervix is thrown into numerous rugæ, and in the lower part there are some papillæ. The mucous membrane is lined throughout with ciliated columnar epithelium, except at the cervix, where it is flattened and non-ciliated.

The **Fallopian Tubes** are contained in the broad ligament, and are between 3 and 4 in. in length. At their inner end they communicate with the cavity of the uterus: they enlarge as they proceed outwards, and end in numerous processes termed *fimbriæ*, one of which is attached to the ovary. These fimbriæ are arranged in a radiating manner around the abdominal opening of the tube. The tube itself consists of a serous, muscular, and mucous

coat. The muscular contains longitudinal and circular fibres, and the mucous membrane is lined by columnar ciliated epithelium.

OVARIES.

The ovaries are small bodies about $1\frac{1}{2}$ in. in length: they weigh from 1 dr. to $1\frac{1}{2}$ drs. each, and are enclosed between the layers of the broad ligament. They are for the most part enclosed by the posterior, and touch the anterior layer at their anterior border; along this line is the hilus where the vessels enter.

Structure.—The ovary is surrounded by a firm fibrous capsule, which is not so firm or dense as the tunica albuginea of the testis. The substance of the ovary consists of a stroma composed of connective tissue, and a few muscular fibre cells and blood-vessels. In this stroma the Graafian follicles are embedded.

The **Graafian Follicles** consist of small vesicles, which are scattered in great numbers through the ovary. The smallest measure about $\frac{1}{100}$ in., and lie in the cortical part. The medium-sized follicles occupy the more central parts, and are about $\frac{1}{50}$ in. diameter, and are few in number. The largest of all, only few in number, lie near the surface, and project from it. The mature follicles are surrounded by a fibrous and a vascular tunic, which have been called the *membrana fibrosa* and *mem-*

brana vasculosa. They are lined internally by several layers of columnar or rounded cells which form the *membrana granulosa,* in which the *ovum* is embedded, and that part of the membrana granulosa which surrounds it, is termed the *discus proligerus.* The vesicle is filled with a serous fluid called the *liq. folliculi.*

THE OVUM.—The ovum is a small round body of $\frac{1}{120}$ in. in diameter. It consists externally of

(1) Zona pellucida or vitelline membrane.
(2) Yelk or vitellus.
(3) Germinal vesicle.
(4) Germinal spot.

The *zona pellucida* is a fine transparent membrane, often marked with fine radiating lines. The *yelk* is a granular mass containing oil globules. The *germinal vesicle* is a clear spot situated on one side of the yelk, and $\frac{1}{720}$ in. in diameter. The *germinal spot* is a dark granular spot of about $\frac{1}{3000}$ in. in diameter.

MENSTRUATION.—In the human female, from the ages of 14 to 45, menstruation takes place every month. The most important event during this period is the escape of an ovum from the ovary. The uterus, Fallopian tubes, and ovaries are congested, a Graafian follicle bursts, and the ovum is picked up by the fimbriated extremity of the Fallopian tube, and passed along towards the uterus.

During this time the mucous membrane of the uterus becomes swollen and congested, and a discharge of blood amounting to several ounces takes place from the uterus. It is probable, also, the mucous membrane of the uterus, including the glands, are discharged during this period. During the few days that menstruation is taking place, there is a feeling of lassitude, with pains in the back and loins.

Corpus Luteum.—After the discharge of the ovum from the Graafian vesicle, there is an effusion of blood into the ruptured follicle, the latter gradually disappears and a sort of scar is formed. But the course of events is greatly influenced if pregnancy occur. If the ovum which was extruded becomes fertilised, certain changes take place. The cells of the membrana granulosa become hypertrophied, and a yellow irregular body is formed termed the corpus luteum. This body goes on enlarging for several months and is still of considerable size at parturition, but shortly after it gradually dwindles away. If pregnancy do not occur, the ruptured follicle shrinks, and in a few weeks is reduced to an insignificant scar.

Impregnation.—The ovum, on entering the Fallopian tube, is passed onwards by the action of the cilia. Its motion is slow, as it appears to spend several days in the Fallopian tube, though this is uncertain. If it meets with no spermatozoa, it dies

and is discharged. But if it becomes impregnated, certain changes immediately begin.

Segmentation of the Ovum.—In the mammal, the whole of the yelk at once takes part in the formation of the embryo, and its ovum is said to be *holoblastic.* In birds, only a part of the yelk at once takes part in the formation of the chick, the rest provides a store of nutritive material for the embryo, and is termed the food yelk. Such an ovum is *meroblastic.* The segmentation of the human embryo has never been observed, but it is presumed to resemble that of other mammals, as the rabbit and dog. Shortly after the ovum has escaped from the Graafian follicle the germinal vesicle disappears: this takes place whether the ovum is fertilised or not. The ovum appears generally to meet with the spermatozoa in the Fallopian tube, and immediately after certain changes begin.

The yelk, which consists of a granular mass of protoplasm, splits into two ovoid masses, and there appears in each a clear space, which resembles a nucleus. Then shortly each ovoid mass splits again, making four, each having a nuclear body. This division goes on, eight, sixteen, thirty-two segments making their appearance, until finally the granular yelk has become a mass of cells, each having a nucleus and cell wall.

In the next change the central parts become fluid, whilst a layer of cells accumulate at the cir-

cumference and form the blastoderm or blastodermic membrane. This membrane at first divides into two, the *epiblast* and *hypoblast*, a third making its appearance in an intermediate position called the *meso-blast.*

Chorion.—Meanwhile the zona pellucida has acquired a new character. It has become beset with numerous villi, giving the ovum a shaggy appearance, and is now termed the *chorion*, and is probably derived from the cells of the epiblast. Shortly after the ovum has entered the uterus it consists of:—

1. Chorion covered with villi.
2. Blastoderm $\begin{cases} \text{Epiblast.} \\ \text{Mesoblast.} \\ \text{Hypoblast.} \end{cases}$
3. Fluid granular contents.

It is from the blastoderm that the fœtal structures are developed: the different layers take the following part in the process.

1. **Epiblast.**—Epidermis and appendages, great nervous centres, principal parts of eye, ear, nose, and one layer of the amnion.

2. **Hypoblast.**—Epithelial lining of the whole alimentary canal, and of the lungs, and one layer of the allantois.

3. **Mesoblast.**—The bones, muscles, fasciæ, peripheral nerves, vascular system, connective tissue, muscular coat of alimentary canal, outer layer of amnion, and part of allantois.

Changes occurring in the Uterus.

Prior to the entrance of the impregnated ovum into the uterus certain changes occur in the character of its mucous membrane, in order to prepare a suitable bed for the reception of the ovum. These changes correspond to those which take place during the menstrual period. They consist essentially in a proliferation of the subepithelial cells, causing a thickening of the mucous membrane, enlargement, and multiplication of the tubular glands, and hypertrophy of the blood-vessels. This thickened membrane is called the *decidua.* Into this decidual membrane the ovum, on entering the uterus, becomes embedded, and into the enlarged glands, or specially formed crypts, the villi of the chorion are received. The decidua having enveloped the ovum, it becomes divided into three distinct parts, viz.: *decidua vera, decidua reflexa,* and *decidua serotina.* The decidua vera lines the general cavity of the uterus, the decidua reflexa is that part which covers the ovum, the term decidua serotina is applied to that portion of membrane which intervenes between the ovum and the uterine walls, and occupies the site of the future placenta.

THE PLACENTA.

During the first two or three weeks the ovum derives its nourishment through the evascular villi of the chorion, the latter taking up some of the al-

buminous matter with which it is surrounded. About the third or fourth week the villi contain delicate loops of capillary blood-vessels, which greatly assist in the absorption of nutrient material. At the end of the sixth to the eighth week (the ovum being about $1\frac{1}{2}$ in. in diameter) the villi which are embedded in the tissues of the decidua serotina, become larger and more complex, and there is a corresponding increase in the decidual membrane, and in the course of another few weeks the placenta is completely developed, while the villi, which correspond to the decidua reflexa, undergo more or less complete atrophy. By the end of the eighth or ninth week the villi can still be separated from the maternal structures, but by the end of the third month, or beginning of the fourth, they are so intimately connected that separation is no longer possible.

The placenta has attained its full development by the end of the fourth month; and when it has attained its full dimensions towards the end of pregnancy it is a flat round cake 7 to 8 inches in diameter.

Structure of placenta.— The placenta when fully formed consists of two portions, a fœtal and maternal. The *fœtal* portion consists of highly complex tufts of villi containing numerous loops of capillary blood-vessels. The *maternal* portion consists of numerous spaces or sinuses continuous with the

blood-vessels of the mother, and which receive and surround the fœtal villi. The villi dip into spaces filled with maternal blood.

Circulation of Blood.—The fœtal blood is carried to the placenta by the two umbilical arteries: it then circulates through the villi and returns to the fœtus through the umbilical vein. The blood is carried to the maternal portion by the uterine arteries, the blood entering the sinuses through the so-called 'curling arteries,' and is returned by the uterine veins. There are no capillaries in the maternal portion, the blood entering the sinuses and returning by the veins.

There is no direct blood communication between the mother and fœtus, but the fœtal villi dip into the maternal blood in a way similar to the intestinal villi, which dip into the contents of the intestine.

Changes effected by the Placenta.

The *fœtal blood gains* nutrient material and O.

" " *loses* effete material (urea, &c.), and CO_2.

The *maternal blood gains* effete material and CO_2.

" " *loses* nutrient material and O.

Structure of umbilical cord.—The umbilical cord when fully developed is from 18 to 20 in. long. Externally it is invested by the amnion, and contains the umbilical vein and two arteries embedded in a gelatinous material termed Wharton's jelly. Early

in fœtal life it contained the omphalo-mesenteric vessels, a second vein, the allantois, and umbilical duct.

FŒTAL CIRCULATION.

The arterial blood coming from the placenta to the fœtus travels along the umbilical vein to the liver. After giving off several branches to the left lobe it divides into two streams, the larger joining the portal vein and thus entering the liver, the smaller passing directly into the inferior vena cava through the *ductus venosus*. In the inferior vena cava the blood carried by the hepatic veins and ductus venosus mixes with the blood which has circulated through the lower extremities. On entering the right auricle the blood of the inferior vena cava is directed by the Eustachian valve, through the foramen ovale into the left auricle, and from thence into the left ventricle. The left ventricle forces it into the aorta, and it is then distributed to the head and upper extremities, a small quantity only passing into the descending aorta. The blood which has circulated through the head and upper extremities returns to the heart along the superior vena cava, the blood then passing into the right ventricle and pulmonary artery. A small part of the blood in the pulmonary artery is conveyed to the lungs, but the major part passes through the ductus arteriosus into the aorta at the commencement of the descending portion. This blood

is distributed to the lower extremities, a certain portion of it entering the hypogastric arteries and being conveyed to the placenta.

Peculiarities of the Circulation in the Fœtus.—The greater part of the blood of the umbilical vein is submitted to the action of the liver, the liver being of large size during fœtal life. The head receives the purest blood that enters the heart, viz. that of the inferior vena cava, while the blood supplied to the lower extremities is that which has already circulated through the head and upper extremities. The great importance of the cephalic nervous centres makes it necessary for them to receive a large amount of arterial blood. It is probable that in early fœtal life the two streams of blood passing through the right auricle are distinct. At a later period, as the foramen becomes smaller, it is possible that some mixture of the two streams may take place.

Changes at Birth.—When the placental circulation ceases, and respiration through the lungs is established, an increased quantity of blood enters the lungs.

The *ductus arteriosus* begins to contract soon after birth, and is completely closed from the fourth to the tenth day.

The *hypogastric arteries* remain patent in their first part as the superior vesicle, but the portion between the bladder and umbilicus becomes obliterated

from two to five days after birth, and remains as the anterior true ligament of the bladder.

The *ductus venosus* and *umbilical vein* become obliterated a few days after birth: the ductus venosus can be traced as a fibrous cord in the fissure of the same name on the under surface of the liver, and the umbilical vein becomes the round ligament.

The *foramen ovale* is closed by the tenth day, and the Eustachian valve is soon reduced to a trace.

THE MAMMARY GLANDS.

The mammary glands form two rounded eminences, which extend from the third to the sixth ribs. A little below their centre is the nipple, which corresponds in position with the fourth interspace. Around the nipple is the areola, which is of a darker colour than the nipple itself.

Structure.—The mammary glands consist of lobes connected together with fat and connective tissue. The lobes consist of lobules, ducts, and blood-vessels. The ducts commence in small clusters of acini, which are lined by short columnar epithelium. The ducts empty themselves into some fifteen or twenty excretory ducts termed *galactophorous ducts*, which converge to the areola, where they form dilatations termed the *ampullæ*, which serve as reservoirs for the milk. The ducts become again contracted, and finally open on the summit of the nipple. The walls of the ducts consist of elastic

tissue, and muscular fibres, and are lined by columnar epithelium, except at their orifices, where it becomes squamous.

Composition of milk.—*See* page 121.

THE TESTES.

The testes occupy the scrotum: they are of an ovoid form, flattened from side to side, are about $1\frac{1}{2}$ in. long, and weigh $\frac{3}{4}$ oz. to an oz. Along the posterior border of the testis is situated the *epididymis,* which is composed of the convolutions of the excretory duct of the testis: the upper part is called the *globus major,* the lower part the *globus minor.*

Structure.—The tests are surrounded by a fibrous capsule, the *tunica albuginea,* the surface of which is covered by the *tunica vaginalis,* except along the posterior border, where the vessels enter. The tunica albuginea passes into the substance of the gland, forming an incomplete vertical septum called the *mediastinum testis.*

Minute Structure.—The testes consist of from 250 to 400 *lobules*: they are conical in shape, their bases being directed towards the circumference of the organ. The lobules are composed almost entirely of minute convoluted tubes, named the *tubuli seminiferi.* Each lobule contains several tubes, the total number having been calculated at 840, and their length $2\frac{1}{4}$ feet each. Their diameter is $\frac{1}{150}$th to $\frac{1}{200}$th in. They consist of a basement membrane,

and in the young subjects are lined internally by cells resembling epithelium. In the adult a mass of cells may be seen, which are spermatozoa in various stages of development.

The **Vasa Recta.**—At the apices of the lobules the tubuli become less convoluted, and unite together to form twenty or thirty larger ducts about $\frac{1}{50}$th in. in diameter called the vasa recta.

The **Rete Testis.**—The vasa recta enter the fibrous tissue of the mediastinum and form a network of tubes called the rete testis.

The **Vasa Efferentia** consist of ten to twenty ducts which emerge from the rete testis. They perforate the tunica albuginea. Their course is at first straight, but they become more and more convoluted as they proceed towards the epididymis, and form a series of small conical masses, the *coni vasculosi.*

The **Canal of the Epididymis.**—The coni vasculosi empty themselves into a single duct, which by its numerous coils forms the globus major and globus minor, and then turns upwards as the vas deferens. The canal is $\frac{1}{70}$th to $\frac{1}{90}$th in. in breadth, is lined by columnar ciliated epithelium, and measures about 20 feet in length.

The **Vas Deferens** is the excretory duct of the testis, and, commencing at the lower part of the globus minor, ascends as part of the spermatic cord to the internal abdominal ring: it is continued to the base of the bladder, where becoming enlarged

and sacculated, it unites with the duct of the vesicula seminalis to form the common ejaculatory duct.

It is about two feet in length, with a narrow canal and thick walls.

Structure.—

1. External or connective tissue coat.
2. Muscular, two longitudinal, and intermediate circular layer.
3. Internal or mucous, arranged in longitudinal folds lined with columnar epithelium.

Spermatozoa.—The spermatic corpuscles consist of a small oval body provided with a long filiform tail. The body is about $\frac{1}{6000}$th in. in length, and the tail about $\frac{1}{400}$th in. in length. The tail performs rapid vibratile movements which enable the spermatozoa to find their way into the Fallopian tube, in spite of the action of the cilia.

The spermatozoa are developed within the cells which line the tubuli seminiferi. The body and coiled-up tail may be seen inside some of these cells from which the spermatozoon makes its escape.

APPENDIX.

Receipts and Losses of a Strong Man in 24 hours.

(Pettenkofer and Voit)

Weight at commencement = 69·29 kilos.
Weight at end = 69·55 „

Grammes in 24 hours		Water	C	H	N	O	Mineral matter
Gains							
Meat . .	139·7	79 5	31 3	1·3	8·5	12·9	3·2
Albumin .	41·5	32·2	5 0	0 7	1·55	2·0	0 3
Bread . .	450·0	208·6	109 6	15·6	5 77	100 5	9 9
Milk . .	500 0	435·1	35 2	5·6	3·15	17·0	3·6
Beer . .	1025·0	961·2	25·6	4 3	0·67	30·6	2 7
Fat . . .	70·0	—	53 5	8 3	—	8·1	—
Butter . .	30·0	2·1	22·0	3 1	0·03	2·8	—
Starch . .	70·0	11·0	26·1	3 9	-	29 0	—
Sugar . .	17·0	—	7·2	1 1	—	8·7	—
Salt . .	4·2	—	—	—	—		4·2
Water . .	286 3	286·3	—	—	—	—	—
Inspired Oxygen	709·0	—	—	—	—	709·0	—
		2016·3 =	—	224·0	—	1792·3	—
Sum of gains .	3342·7		315·5	270·9	19 47	2712·9	23 9
Losses							
Urine . .	1343·1	1278·0	12·60	2·75	17·35	13 71	18 1
Fæces . .	114·5	82·9	14 50	2·17	2·12	7·19	5·9
Expired products	1739·7	828·0	248·60	—	—	663·10	—
		2189·5 =	—	243·22	—	1946·20	—
Sum of losses .	3197·3	—	275·70	248 22	19·47	2630·20	24 0
Difference, gains, minus losses	145·3	—	+39·8	+22·7	0	+82 7	−0·11

Metric System.

One metre equals 39·37 English inches.

10 decimetres	=	1 metre.
100 centimetres	=	,,
1,000 millimetres	=	,,

One decimetre or 10 centimetres are nearly equal to 4 inches, and 25·4 millimetres equal an inch.

One gramme	=	15·43 grains.
10 decigrammes	=	1 gramme.
100 centigrammes	=	,,
1,000 milligrammes	=	,,
1,000 grammes	=	1 kilogramme.
One cubic centimetre weighs		1 gramme.
1,000 cubic centimetres	=	1 litre.
1 litre	=	35 fluid oz.
100 c.c.	=	$3\frac{1}{2}$ oz.

Thermometer Scales.

1. Fahrenheit's scale, commonly in use in England, has its boiling point at 212°, and freezing point at 32°.

2. Centigrade scale in use on the continent, and universally in scientific works in this country, has a boiling point at 100°, and freezing at 0°.

To reduce Fahrenheit to Centigrade, subtract 32 and multiply by 5 and divide by 9. $C = (F - 32) \times \frac{5}{9}$.

To reduce Centigrade to Fahrenheit, multiply by 9 and divide by 5, then add 32. $F = (C \times \frac{9}{5}) + 32$.

Thus to reduce 212° F. to C.

$$C = 212 - 32 \times \tfrac{5}{9}.$$
$$= 180 \times \tfrac{5}{9}.$$
$$= 100.$$

Reduce 100 C. to F.

$$F = 100 \times \tfrac{9}{5} + 32.$$
$$= 180 + 32.$$
$$= 212.$$

QUESTIONS IN PHYSIOLOGY.

(1.) Describe the mechanism by which the air is moved during ordinary and extraordinary inspiration and expiration, what parts of the nervous system are concerned, and how it can be proved that they are concerned in ordinary respiration.

(2.) Describe the minute structure of the spleen, the difference between the blood of the splenic artery and that of the splenic vein; what opinions are entertained regarding the functions of the organ, and what are the reasons for these opinions?

(3.) Give an account of the function of the intracardiac nervous apparatus, and the connections and functions of the extracardiac nerves.

(4.) Describe the minute structure of the retina. Mention the anatomical and physiological facts that prove the rods and cones to be the peripheral terminal organs of the optic nerve.

(5.) Give an account of the minute structure of the ovary, the manner in which the Graafian follicle and its contents are developed, the changes in the follicle that precede and those that follow its rupture.

(6.) How much of the several groups of essential food-stuffs is needed for the maintenance of health by a man doing severe muscular work, and by a man doing an average amount of muscular work, respectively?

(7.) Give an account of the minute structure of the several parts of the auditory labyrinth, and of the theories advanced with regard to their functions.

(8.) What are the functions of the portio dura nerve? Describe the physical and chemical qualities of chyle, and the changes it undergoes in its course from the intestines to the thoracic duct.

(9.) Describe the structure of the fibres of a voluntary muscle, and of the heart; and the phenomena of contraction in voluntary and involuntary muscle.

(10.) Describe the changes which the blood undergoes in passing through the capillaries of the skin and lungs.

(11.) What is the minute anatomy of adipose tissue, and what purpose does fat serve in the animal economy?

(12.) What is the action of the arteries in the circulation of the blood? What evidence can you offer of the influence of the nervous system on this action?

(13.) Describe the structure of the pancreas, and state the effects of the pancreatic juice on the chief constituents of the food.

(14.) Describe in detail one complete revolution of the heart's action.

(15.) Trace the changes by which the temporary are replaced by the permanent teeth, and state the period at which each of the permanent teeth generally appears.

(16.) Compare the effects of active and prolonged exercise with the ordinary changes which take place in the body during rest.

(17.) Describe the structure and functions of the true vocal cords. How is speech effected?

(18.) Describe the structure of the crystalline lens and the changes which occur in it during accommodation.

(19.) State the average quantity and specific gravity of the urine; enumerate its chief constituents, and the circumstances which affect their proportion.

(20.) Enumerate the various form of cartilage, describing the minute character of each, and mention the joints in which interarticular fibro-cartilage is found.

(21.) Explain the effect of complete division of the spinal column between the second and third cervical vertebræ in one of the higher animals.

(22.) Describe as fully as you can the phenomena presented by the circulation of the blood, as may be seen in some transparent part under the microscope.

(23.) How are the acts of inspiration and expiration accomplished? Describe the changes produced in the air by respiration.

(24.) Enumerate the functions of the sympathetic system of nerves, and give examples of each function.

(25.) What are the proofs that the blood is a living fluid? What are the proofs that it circulates? and what is its composition?

(26.) Describe the arrangement and relation of the several structures which enter into the formation of a lobule of the liver.

(27.) How is the voice produced and modulated? State by what muscles the rima glottidis is influenced, and how they act in changing its shape.

(28.) Describe the arrangement of the tubuli uriniferi in the cortical and in the medullary portions of the kidney. State how the capillaries and arteries are distributed in this organ. Give an analysis of the urine.

(29.) Describe the structure of the duodenum, and the changes the food undergoes in that part of the intestine.

(30.) Describe the process of growth in a long bone.

(31.) Describe the mucous membrane of the tongue, and the functions of the nerves which supply it.

(32.) What is the influence of food, exercise, and season on the organic and inorganic salts of the urine?

(33.) What is the nature of the arterial pulse, and what are the conditions in ordinary health which have most influence upon its rate and character?

(34.) Explain physiologically how a tumour in the neck may cause loss of voice, and how a small foreign body in the larynx may cause great dyspnœa.

(35.) What changes occur in an ovum from the time of impregnation up and to inclusive of the formation of the three embryonal sacs?

(36.) Describe the effect of dividing the vagi in a mammal.

(37.) What are the sources of heat in the animal body? In what organs is it principally produced, and by what means is it regulated?

(38.) Define the terms eupnœa, dyspnœa, asphyxia, apnœa.

(39.) Describe the phenomena witnessed when the trachea of a rabbit is suddenly occluded?

(40.) What is the function of the iris with reference to distinct vision? Describe briefly the relations of the iris to the nervous system?

(41.) Describe the minute structure of the small intestine, and the manner in which the food passes from the intestines into the circulation.

(42.) State the principal facts which indicate the influence of the nervous system on secretion.

(43.) What is meant by an inhibitory nerve? Give an instance.